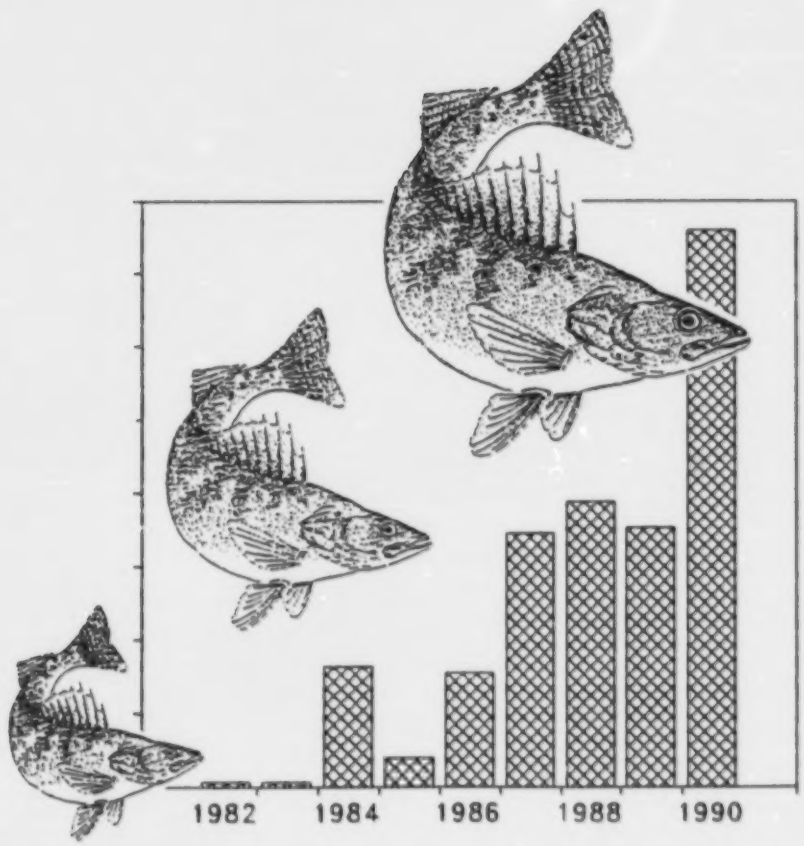
Saskatchewan Parks and Renewable Resources

# Evaluation of Walleye (*Stizostedion vitreum*) Fingerling Stocking Programs in Three Saskatchewan Lakes

**Technical Report 91-4**



# EVALUATION OF WALLEYE (*Stizostedion vitreum*) FINGERLING STOCKING PROGRAMS IN THREE SASKATCHEWAN LAKES

BY

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# EXECUTIVE SUMMARY

## OBJECTIVE

Focus of the walleye stocking program in Saskatchewan has shifted in recent years from stocking with fry to fingerlings. The number of lakes stocked with fingerlings has increased from four in 1982 to 20 in 1990 with a total of over 2.2 million fingerlings being stocked over the years. Consequently, there is a need to assess the success of the new stocking program.

The objective of the present study was to evaluate the success of the fingerling stocking programs in Delaronde, Greig, and Turtle Lakes.

## METHODS OF ASSESSMENT

A standard gang of gill nets was used primarily to sample fish populations in the lakes. In addition, various lengths of small mesh nets were used in order to catch younger walleye.

Greig Lake was sampled from 1988 to 1990. Delaronde and Turtle Lakes were netted during the summer of 1990.

Length, weight, relative weight, growth, maturity, and survival data were used to assess population characteristics. Population abundance was estimated from catch per unit effort data calculated from standard gang

catches.

Information derived from population abundance, survival and stocking records was used to estimate the contribution of stocked walleye to year-class strength.

## CONCLUSIONS AND RECOMMENDATIONS

**Greig Lake** - Stocking of fry in the past in Greig Lake had failed. On the other hand, recent stocking of fingerlings has been very successful in establishing an excellent walleye population in this lake. The abundance of walleye has increased 42 times since the last survey conducted in 1966. Walleye has now become the most abundant large fish species in the lake.

Although some of the stocked walleye have already become sexually mature, natural reproduction in the lake has not occurred due to lack of spawning habitat. Therefore, the walleye population in Greig Lake has to be maintained by regular stocking of fingerlings. However, if suitable artificial spawning reefs are provided, the walleye may be induced to spawn in the lake and natural recruitment may be able to maintain the population in the future.

**Turtle Lake** - There are eight times more walleye in the lake now than there were in the mid-1960s due largely to the stocking program. Unlike in Greig Lake, fry and fingerling stockings may be equally successful in Turtle Lake, provided that large numbers (in the order of millions) of fry are used.

This is probably because Turtle Lake is more fertile than Greig Lake and provides more suitable zooplankton as food for the newly stocked walleye fry.

Turtle Lake has only marginal spawning habitat for walleye. Recruitment from natural reproduction has usually been small and unreliable. Therefore, the size of the walleye population has always been small when not maintained by proper stocking. Rough calculations indicate that stocking one fingerling is equivalent to stocking nine fry in terms of survival from stocking to age 3. The cost ratio of fry to fingerling stocking is estimated at 1:40, using the average fingerling production cost of $0.36 per fingerling from the Meadow Lake Ponds. Thus, in Turtle Lake it makes more economic sense to stock fry rather than fingerlings.

**Delaronde Lake** - The increase in walleye abundance in Delaronde Lake in response to stocking is less dramatic compared to the other two lakes: only 1.3 times more walleye are found in the lake now than in 1975. While undoubtedly some stocked walleye fingerlings survived in Delaronde Lake, the number stocked is yet too small to make a significant impact on the walleye population.

Natural recruitment into the walleye population in Delaronde Lake apparently has been poor since the 1970's. Therefore, in order to greatly enhance the walleye population in this lake, the rate of stocking must be increased to at least about 20 fingerlings$\cdot ha^{-1}$, or about 171,000 fingerlings

per year.

Based on the findings of the present study, the following management options are recommended:

**A. General recommendations regarding supplemental stocking of walleye in Saskatchewan:**

1. Prior to stocking, factors causing the decline or collapse of the walleye stock should be investigated. If the cause is deterioration or lack of spawning habitat, then rehabilitation of existing or creation of new spawning habitats should receive the highest management priority.
2. Lakes without spawning habitat should not be stocked, unless the objective of stocking is to provide a put-grow-take sport fishery.
3. Fry instead of fingerlings should be stocked in lakes where adequate quantities of suitable zooplankton are present at time of stocking. However, the number of fry used must be relatively large: a minimum rate of 200 fry·ha$^{-1}$ may be required. This means millions of fry may be needed for just one lake. Consequently, only a few lakes can be stocked each year, considering the number of fry that can be produced at the hatchery. Therefore, lakes for stocking should be carefully chosen on the basis of zooplankton food supply,

forage fish abundance, spawning habitat and the status of native fish stocks.

4. To reduce costs, the more expensive fingerling stocking should only be conducted in lakes where suitable zooplankton food source is scarce at time of stocking, but forage fish are abundant. A minimum stocking rate of 20 fingerlings·ha$^{-1}$ is recommended. The recommended minimum rates of stocking for fingerlings and fry are low, but are realistic in view of the numbers of fingerlings and fry that can be produced each year.
5. Stocking should be continued for a minimum of four years to provide enough year classes so that natural reproduction may restore a healthy self-sustaining stock.
6. The stocked walleye should be monitored and assessed for natural reproduction. Stocking should be discontinued if natural recruitment cannot be established. Creel surveys are needed to determine the contribution of stocked walleye to the sport fishery and to provide information for cost-benefit analyses.

**B. Lake specific**

**1. Greig Lake**

i. Construct artificial spawning reefs in the lake.

ii. Stock fingerlings at a rate of 60 fingerlings·ha$^{-1}$, or 97,200 fingerlings each year until natural recruitment is established.

2. **Turtle Lake**

i. Construct artificial spawning reefs in the lake.

ii. Stock fry at a rate of 200 fry·ha$^{-1}$ (approximately, 1,300,000 fry total), or 20 fingerlings·ha$^{-1}$ (128,000 fingerlings total) every other year until natural reproduction is capable of establishing a healthy self-sustaining stock.

iii. Conduct a scale/otolith-pattern analysis to determine if discernible "checks" can be found to identify the origin of the walleye fingerlings (i.e., from rearing ponds, stocking or natural reproduction).

3. **Delaronde Lake**

i. Rehabilitate spawning habitat in the tributary streams.

ii. Stock 20 fingerling·ha$^{-1}$ (about 173,00 fingerlings total) every other year until natural reproduction is capable of establishing a healthy self-sustaining population.

## ACKNOWLEDGEMENTS

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# 1. INTRODUCTION

Walleye stocking in Saskatchewan has traditionally been done with newly hatched fry. However, lack of success with previous stocking in many water bodies has shifted the focus in recent years from stocking with fry to fingerlings. In 1982, Fisheries Branch of Saskatchewan Department of Parks and Renewable Resources began experimenting with rearing walleye from fry to fingerling size in small, shallow natural water bodies (Liaw 1984, 1987).

As indicated in Table 1, the number of fingerlings stocked during the first few years was small. However, it has increased noticeably since 1986 when three constructed ponds were added to the fingerling rearing program.

The number of water bodies stocked with walleye fingerlings in each year varies from 3 to 20. So far 22 different water bodies have been stocked. Of these, six lakes have been stocked for at least 4 years with moderate quantities of fingerlings. The status of the stocked walleye in these lakes has yet to be evaluated to see if the stocking program has been successful.

Table 1. Total numbers of walleye fingerlings and water bodies stocked in each year since 1982.

| Year | No. water bodies stocked | No. fingerlings stocked |
|---|---|---|
| 1982 | 4 | 6,910 |
| 1983 | 4 | 6,960 |
| 1984 | 3 | 164,360 |
| 1985 | 3 | 40,500 |
| 1986 | 9 | 154,500 |
| 1987 | 9 | 345,000 |
| 1988 | 16 | 387,340 |
| 1989 | 13 | 353,130 |
| 1990 | 20 | 758,930 |

## 2. OBJECTIVES

The objectives of the present study were to assess the status of walleye populations in three lakes (Delaronde, Greig, and Turtle) and to evaluate the success of the walleye fingerling stocking program for these lakes.

## 3. THE LAKES AND THEIR WALLEYE STOCKING HISTORY

### 3.1 DELARONDE LAKE (54°03′ 107°03′; map 73J/3)

Delaronde Lake is located in central Saskatchewan west of the Prince Albert National Park, and is about 11 km northeast of Big River. The lake has a drainage area of 1,398

$km^2$. It drains into the Churchill River at Lac Ile-a-la Crosse via Taggart Creek, Cowan and Beaver Rivers. The limnology and fishery of the lake are documented in Liaw (1976).

The lake consists of two distinct basins, separated by a short and narrow channel. The northern basin (48.8 $Km^2$) has a mean and a maximum depth of 13.4 m and 49.8 m respectively. The shallow, larger southern basin ( 85.7 $Km^2$) has a mean depth of only 3.8 m and a maximum depth of 7.0 m. The lake has a water retention time of about 8 years.

The lake's fish resource consists of lake whitefish, cisco, northern pike, white sucker and walleye. Lake whitefish and cisco are more abundant in the northern basin, whereas northern pike, white sucker and walleye are more common in the southern basin. The northern pike and the walleye are harvested mainly by sports fishermen, whereas the lake whitefish are harvested by commercial fishermen only. White sucker and cisco are largely unused.

Continuous sharp decline in the commercial catch of walleye since the mid-60's (Fig. 1) was taken to indicate a collapsing walleye population in the lake. As a result, a walleye enhancement program was initiated in 1981. The program involved rearing walleye fry in a lake-side rearing pond (Shore Pond) and later releasing them as fingerlings into the lake. Since 1981 a total of 233,120 walleye fingerlings have been released from this pond into Delaronde Lake (Table 2).

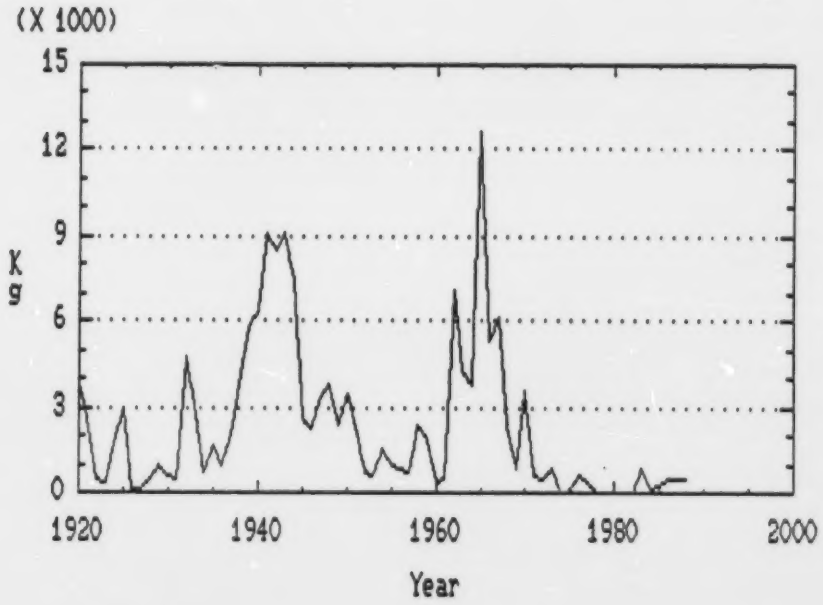


Fig. 1. Historical record of walleye production by the commercial fishery of Delaronde Lake.

Table 2. Numbers of walleye fingerlings released from Shore Pond into Delaronde Lake since 1981.

| Year | Number | Year | Number |
|---|---|---|---|
| 1981 | 440 | 1986 | 3660 |
| 1982 | 1,520 | 1987 | 0 |
| 1983 | 2,900 | 1988 | 80 |
| 1984 | 160,590 | 1989 | 11,930 |
| 1985 | 30,000 | 1990 | 22,000 |
| | | Total | 233,120 |

## 3.2 GREIG LAKE (54°27'108°43'; map 73K/7)

Greig Lake is a popular recreational water body located in the Meadow Lake Provincial Park. It has a water area of 16.2 $km^2$, a maximum depth of 27 m and a mean depth of 10 m. Background information on the limnology and fishery of this lake can be found in Lane (1967).

Larger fish species in Greig Lake consist of lake whitefish, northern pike, white sucker, yellow perch, burbot and walleye.

The commercial fishery exploits mainly lake whitefish, although small quantities of northern pike and walleye may also be caught. The sport fishery harvests almost exclusively northern pike and walleye.

A moderate walleye population had existed in Greig Lake until the late 1930s, with an average annual commercial harvest of 460 kg being recorded between 1921 and 1936. Since

then, the walleye population became very small or almost non-existent until recently when walleye fingerlings were stocked.

Many attempts have been made in the past to enhance the walleye population in the lake. Between 1946 and 1983, a total of 4.4 million fry were stocked (Table 3). Very poor catches of walleye in survey nets until recently indicate these fry plantings have failed to improve the walleye population in this lake.

Table 3. Record of walleye fry stocking in Greig Lake.

| Year | Number | Year | Number |
|---|---|---|---|
| 1946 | 700,000 | 1958 | 400,000 |
| 1952 | 300,000 | 1966 | 200,000 |
| 1953 | 300,000 | 1968 | 500,000 |
| 1954 | 230,000 | 1982 | 400,000 |
| 1956 | 532,000 | 1983 | 300,000 |
| 1957 | 500,000 | Total | 4,362,000 |

The apparent failure of fry stocking prompted the establishment of a small (1.8 ha), lake-side rearing pond in 1982. In the first year fewer than 300 fingerlings were released, but substantially more were produced and released in the following years (Table 4).

Table 4. Record of walleye fingerling stocking in Greig Lake.

| Year | Number | Year | Number |
|---|---|---|---|
| 1982 | 284 | 1986 | 0 |
| 1983 | 1,000 | 1987 | 97,200 |
| 1984 | 1,900 | 1988 | 9,500 |
| 1985 | 7,500 | 1989 | 6,200 |
| | | Total | 123,584 |

Use of the lake-side pond was terminated in 1987 when two rearing ponds were constructed at Meadow Lake. The fingerlings released since 1987 came from these two Meadow Lake ponds. Fingerling stocking was temporarily discontinued in 1990.

### 3.3 TURTLE LAKE (53°36'108°38'; map 73F/10)

Turtle Lake is situated in west-central Saskatchewan, about 100 km northwest of North Battleford. Background information on the limnology and fishery is documented in Sawchyn (1967). Results of an angling survey (1980) are reported in Tinline & Durbin (1982).

The lake has a watershed area of approximately 474 $km^2$. It drains into the North Saskatchewan River only in the spring via the Turtle River. The lake has a water area of 64 $km^2$, a mean depth of 6.3 m and a maximum depth of 14.3 m.

Large fish species in Turtle Lake include lake

whitefish, cisco, white sucker, northern pike, walleye, yellow perch and burbot. A commercial fishery existed for more than six decades until the 1970's when the lake whitefish population collapsed.

Recreational fishing harvests predominantly northern pike, although occasionally small quantities of walleye are also caught.

Attempts to increase the quality of angling give Turtle Lake a long history of walleye stocking. A total of 26.2 million walleye fry and eyed eggs were stocked during the period, 1941-86. The number of fry stocked within the last 10 years is presented in Table 5.

Table 5. Record of walleye fry stocking in Turtle Lake within the last 10 years.

| Year | Number | Year | Number | Year | Number |
|---|---|---|---|---|---|
| 1980-81 | 0 | 1984 | 800,000 | 1987-90 | 0 |
| 1982 | 500,000 | 1985 | 1,800,000 | | |
| 1983 | 400,000 | 1986 | 5,800,000 | Total | 9,300,000 |

Poor catches of walleye in the commercial and sport fisheries, as well as in survey nets until recently suggest most fry plantings had failed to establish a self-sustaining walleye population in this lake. Consequently, from 1986 the emphasis of walleye stocking has been shifted from fry to pond-reared fingerlings. Table 6 lists the number of walleye fingerlings stocked by year and origin.

Table 6. Record of walleye fingerling stocking in Turtle Lake.

| Year | Number | Origin |
|---|---|---|
| 1986 | 4,670 | Glaslyn Pond |
| 1988 | 89,290 | Meadow L. Ponds |
| 1989 | 28,640 | Meadow L. Ponds |
| 1990 | 239,000 | Meadow L. Ponds |
| Total | 361,600 | |

# 4. METHODS

## 4.1 SAMPLING

### 4.1.1 Delaronde and Turtle Lakes

Sampling of fish from Delaronde and Turtle Lakes in the summer of 1990 was conducted primarily with a full set of standard gang gill nets which consisted of 45.66 m each of 3.8 cm, 5.1 cm, 7.6 cm, 10.2 cm 12.7 cm and 14.0 cm stretched mesh (total length = 274 m). The nets were usually set in the afternoon and lifted the following morning.

In addition to the standard gang nets, a 20 m long 5.1 cm mesh gill net was also used on Delaronde Lake in order to catch younger walleye.

Extra gill nets used on Turtle Lake included a 20 m long 5.1 cm mesh net and two sets of partial standard gang nets. The latter consisted of 10 m each of 3.8 cm to 14.0 cm stretch mesh as in the standard gang net. When in use the two

sets were tied together to make a total length of 120 m.

### 4.1.2 Greig Lake

Sampling from Greig Lake on July 12, 1988 was done with 260 m of gill nets consisting of two 60 m gangs of 3.8 cm to 14.0 cm meshes, and two 70 m gangs of 2.5 to 14.0 cm meshes. The sampling was conducted as a regular sport fish management survey.

Between July 14, 1988 and August 4, 1989 various lengths of 2.5 cm stretched mesh monofilament gill nets were used to capture walleye. Occasionally trap nets were also used, but they failed to capture any walleye. On May 24, 1990 a 20 m long 3.8 cm mesh and a 10 m long 5.1 mesh gill nets were used.

## 4.2 MEASUREMENTS AND DATA ANALYSES

Fork lengths, total lengths, weights, stomach contents and maturity stages were recorded from nearly all of the walleye caught. Scale and otolith samples were taken for age determination.

Growth data were fitted to three growth functions (von Bertalanffy, Gompertz and Logistic) using the microcomputer program "FISHPARM" (Prager, et al. 1987). An explanation of the growth parameters in each growth function is provided in Appendix 1. The optimal function was chosen on the basis of a smaller sum of squares of the residuals, a

larger value of $R^2$ (coefficient of determination) and the appropriateness of derived growth parameters (i.e., whether the asymptotic size and the growth coefficient are intuitively realistic).

Relative weight ($W_r$) is used to evaluate the condition of the walleye. It is calculated as 100 x $W/W_s$, where W is the weight of an individual fish, and $W_s$ the "standard" weight of a fish of the same length. The equation for $W_s$ for North American walleye (Murphy, et al. 1990) is:

$$\log_{10} W_s \text{ (g)} = -5.453 + 3.180 \log_{10} \text{total length (mm)}$$

Walleye smaller than 150 mm total length were excluded from the calculation (due to greater error in weighing smaller fish and changes in body form as they develop from juveniles to adults).

## 5. RESULTS

### 5.1 DELARONDE LAKE

#### 5.1.1 The Catch

A total of 50 walleye along with other species were caught from the southern basin of Delaronde Lake during the summer of 1990. A summary of the total catch by species is presented in Table 7 and Appendix 2. The catch of the standard gang gill net indicates that northern pike is the most abundant large fish in the southern basin of Delaronde Lake, followed by white sucker. Walleye are not numerous: their

catch per unit effort is only 2.8. A comparison of the results of the present survey with that of the 1975 (Liaw 1976) indicates that the status of the fish populations in the south basin of Delaronde Lake has not changed much, except that the walleye population appears to have improved slightly: the 1975 survey had a slightly lower catch per unit effort of 2.1.

A meaningful comparison cannot be made between the standard gang and the 5.1 cm mesh net because of differences in mesh size and length. However, the results can be compared with that of other lakes using same type of nets.

Table 7. Total number of fish caught by species from Delaronde Lake (southern basin) during the summer of 1990, together with per cent composition and catch per unit effort data.

| Species | Standard gang (6 sets) | | | 5.1 cm mesh net (4 sets) | | |
|---|---|---|---|---|---|---|
| | No. | % | CPUE* | No. | % | CPUE* |
| walleye | 47 | 9.3 | 2.8 | 3 | 11.5 | 3.8 |
| northern pike | 277 | 55.1 | 16.7 | 21 | 80.8 | 26.2 |
| white sucker | 128 | 25.4 | 7.7 | 1 | 3.8 | 1.2 |
| yellow perch | 23 | 4.6 | 1.4 | 1 | 3.8 | 1.2 |
| cisco | 16 | 3.2 | 1.0 | 0 | 0.0 | 0.0 |
| lake whitefish | 12 | 2.4 | 0.7 | 0 | 0.0 | 0.0 |
| total | 503 | 100 | 30.4 | 26 | 99.9 | 32.5 |

**Catch Per Unit Effort: catch·(100 m net-day)$^{-1}$*

### 5.1.2 Size Distribution and Relative Weights

The fork lengths of the walleye caught in 1990 ranged from 200 mm to 624 mm, with an average of 396 mm, a median of 385 mm and a mode of 380 mm (Fig. 2). Walleye in the 1975 survey had a smaller size range, from 213 mm to 480 mm, with a mean, a median and a mode of 365 mm, 356 mm and 350 mm, respectively.

Both total and fork lengths were recorded from 50 walleye ranging from 200 to 624 mm in fork lengths and 213 to 651 mm in total lengths. The regression equation derived from these data is as follows: $TL=9.213+1.036FL$ ($R^2=0.998$, standard error of estimate = 3.322).

The weights of the walleye varied between 80 g and 3,000 g, with an average of 766 g, a median of 600 g and a mode of 500 g (Fig. 3). By comparison, the weights of the 1975 walleye ranged from 110 to 1,400 g with a mean, a median and a mode of 563, 425 and 400 g, respectively.

The weight-length relationship calculated from the 1990 sample is shown in Fig. 4. The regression equation can be used to obtain approximate weights from fork length data.

Frequency distribution of relative weights of the walleye caught in 1990 is compared with those caught in the 1975 survey in Fig. 5. A t-test indicates that the 1990 population (average $W_r$= 88) has significantly ($p<0.05$) better

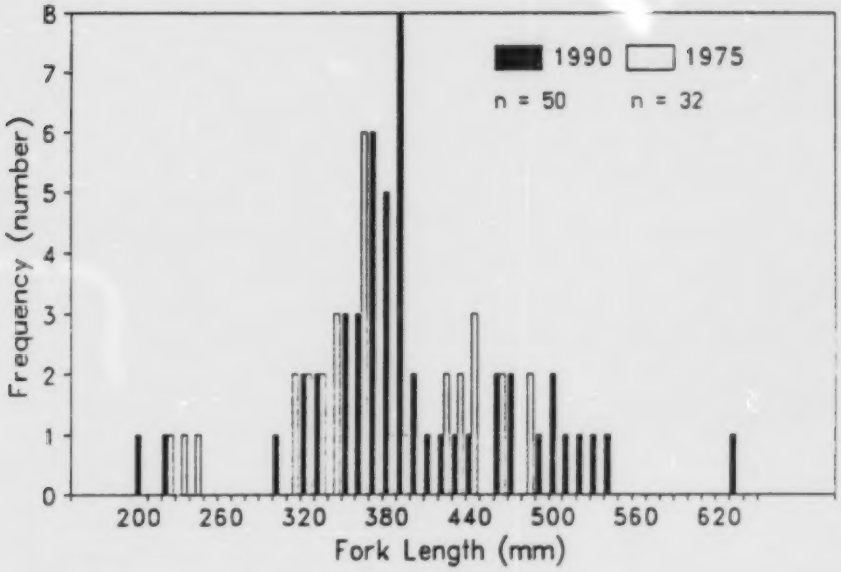


Fig. 2. Length frequency distribution of walleye in the South Basin of Delaronde Lake in 1975 and 1990.

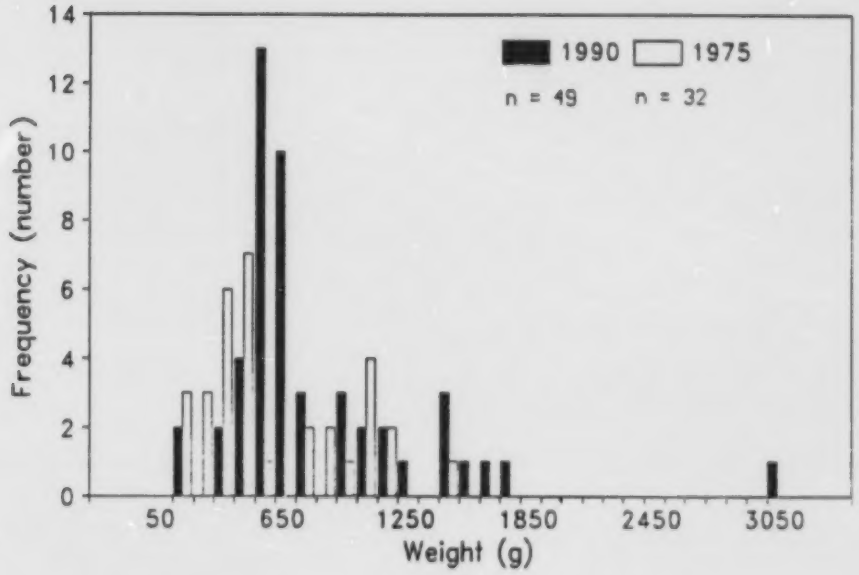


Fig. 3. Weight frequency distribution of walleye in the South Basin of Delaronde Lake in 1975 and 1990.

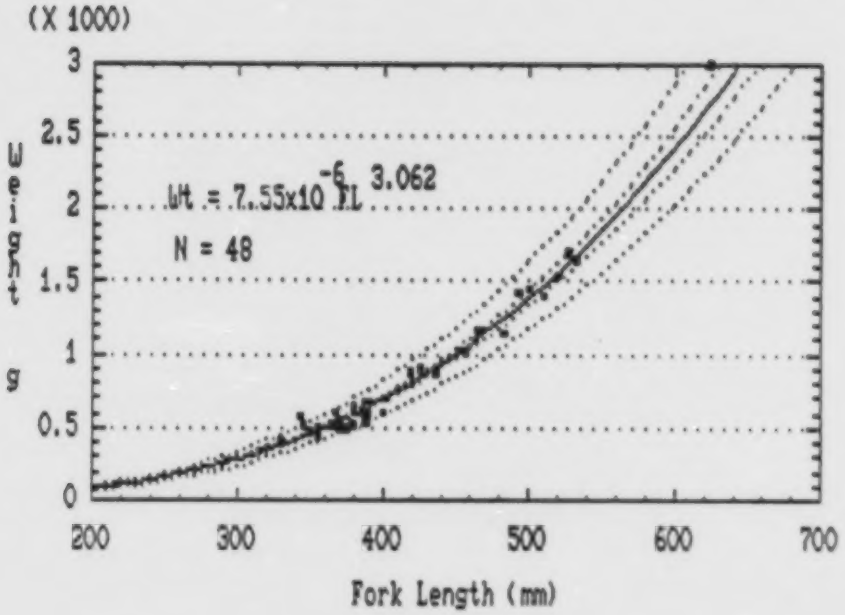


Fig. 4. Weight-length relationship of walleye in Delaronde Lake in 1990. Outer and inner dotted lines indicate 95% confidence limits of predicted values and means, respectively.

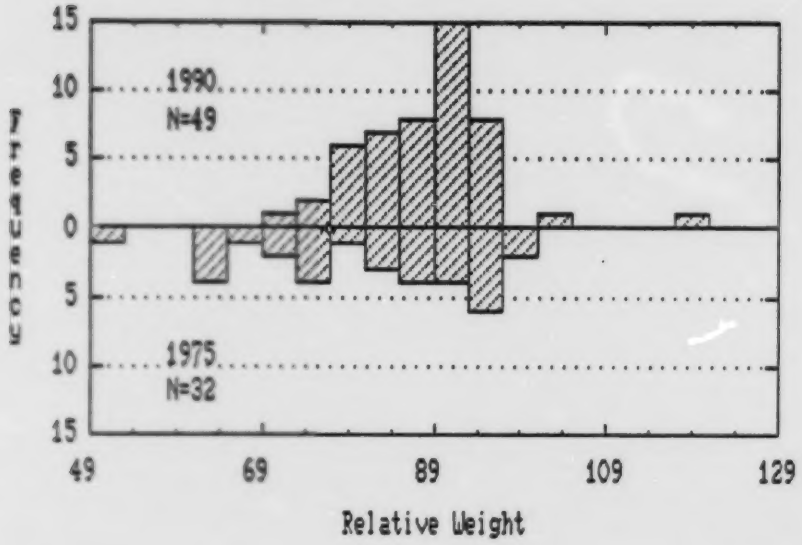


Fig. 5. Relative weights of walleye in Delaronde Lake. A comparison of 1990 and 1975 data.

condition than the 1975 population (average $W_r$ = 82).

### 5.1.3 Age Composition, Growth and Size at Maturity

Both scale and otolith samples were used for ageing. Since there is a good agreement between these two ageing methods within the age range, either can be used to determine the ages of walleye from this lake. Otolith ages were used in the growth analysis.

The walleye caught in 1990 ranged from 2 to 13 years in age. The age composition of these fish (Table 8) indicates the presence of three strong year classes (1984, 1985 and 1986). The 1986 year class is particularly strong, accounting for over 57% of the total catch.

Table 8. Age composition of walleye caught in Delaronde Lake in 1990.

| Age | Year class | Number | % | Age | Year class | Number | % |
|---|---|---|---|---|---|---|---|
| 2 | 1988 | 1 | 2.0 | 6 | 1984 | 5 | 10.2 |
| 3 | 1987 | 4 | 8.2 | 7 | 1983 | 2 | 4.1 |
| 4 | 1986 | 27 | 57.1 | 10 | 1980 | 1 | 2.0 |
| 5 | 1985 | 6 | 12.2 | 13 | 1977 | 2 | 4.1 |

Size-at-age data are fitted to the von Bertalanffy growth function (Figs. 6 & 7 ). The asymptotic sizes for the population based on 1990 data are 554 mm in fork length and

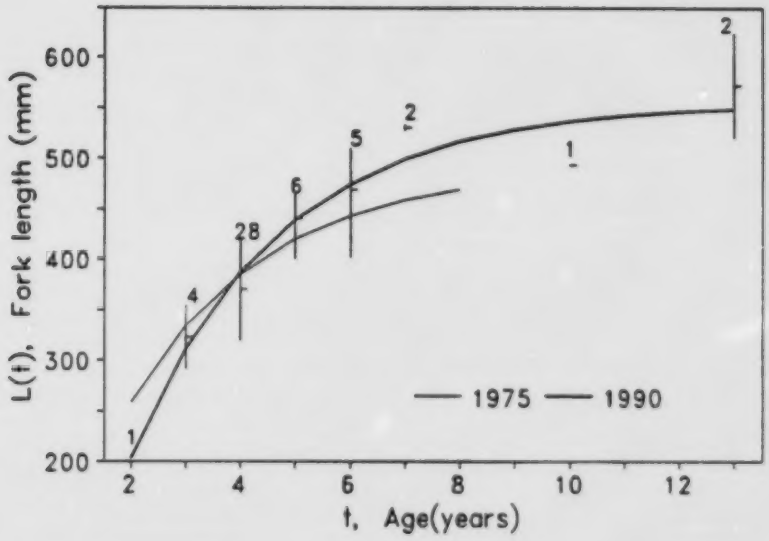


Fig. 6. Average length-at-age of walleye in Delaronde Lake fitted to the von Bertalanffy growth curve:

$$L_{(t)}=L_{\infty}(1-\exp(-K(t-t_0))),$$

where $L_{\infty}$=554 mm, K=0.3713 and $t_0$=0.7753 for the 1990 data and $L_{\infty}$=491 mm, K=0.3926 and $t_0$=0.0968 for the 1975 data. Vertical bars indicate range, tick marks on bars indicate averages and numbers above bars are sample sizes for the 1990 data. For the 1975 data, only the growth curve is shown.

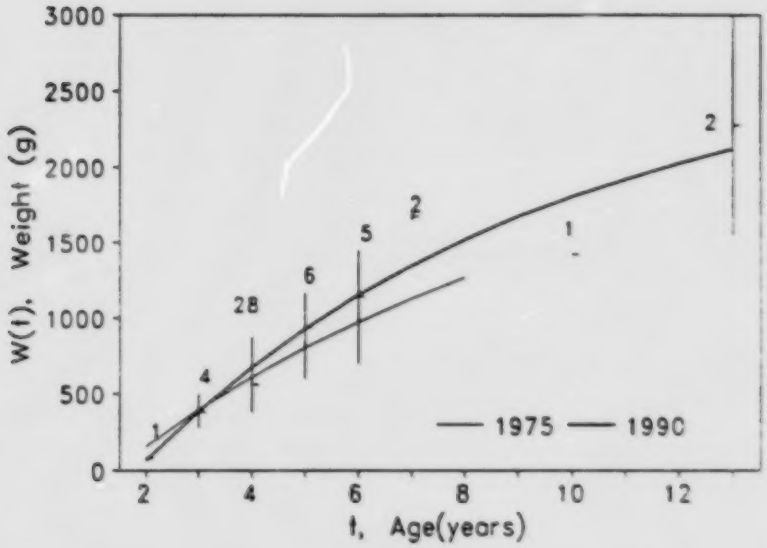


Fig. 7. Average weight-at-age of walleye in Delaronde Lake fitted to the von Bertalanffy growth curve:

$$W_{(t)}=L_{\infty}(1-\exp(-K(t-t_0)))$$

where $W_{\infty}$=2791 g, K=0.1276 and $t_0$=1.827 for the 1990 data and $W_{\infty}$=2486 g, K=0.108 and $t_0$=1.396 for the 1975 data. Vertical bars indicate range, tick marks on bars indicate average and numbers above bars are sample sizes for the 1990 data. For the 1975 data, only the growth curve is shown.

2,791 g in weight. If growth follows the current pattern, 95% of the asymptotic length and weight (generally considered the maximum size - Moreau 1987) will be reached by about 9 and 25 years of age, respectively. A t-test indicates there are no significant differences in the predicted size-at-age between 1975 and 1990 surveys.

Size at maturity (the size at which 50% of the fish reach sexual maturity) cannot be accurately calculated due to insufficient samples within each size group. However, the data obtained suggest that female walleye in Delaronde Lake mature at a fork length of approximately 420 mm and males at about 400 mm.

### 5.1.4 Survival and Mortality Rates

Instantaneous rate of total mortality (Z) can be calculated from the catch curve derived from age composition data (Ricker 1975). The value (0.810) calculated for the age groups 4-7 in the 1990 population is much higher than that (0.318) for the age groups 3-8 in the 1975 population. The corresponding annual survival rates (S) are 44% and 73%, respectively.

Instantaneous rate of natural mortality (M) can be estimated from von Bertalanffy's growth parameters ($L_\infty$ and K) and mean annual surface water temperature (T) according to the empirical equation of Pauly (1980):

$$\log_{10}M=-0.0066-0.279\log_{10}L_{\infty}+0.6543\log_{10}K+0.4634\log_{10}T$$

where $L_{\infty}$ is in cm and T is in °C.

Using a temperature value of 5° C and the growth parameters shown in Fig. 6, the walleye population in Delaronde Lake had instantaneous natural mortality rates of 0.367 (based on 1990 data) and 0.380 (based on 1975 data). Since Z=M+F (Ricker 1975), the corresponding rates of fishing mortality (F) can be calculated: 0.44 for the 1990 population and 0 for the 1975 population. The 0.44 instantaneous fishing mortality is equivalent to an annual rate of exploitation of 30% (u=FA/Z). All mortality for the 1975 population was probably due to natural causes.

## 5.2 GREIG LAKE

### 5.2.1 The Catch

Several types of gear were used to catch walleye from Greig Lake. Only catches in those gill nets set overnight were used to calculate catch per unit effort. The results are shown in Tables 9-11. These results indicate that next to yellow perch, walleye is the most abundant large fish in Greig Lake, contributing up to 36.5% of the total catch. Its catch per unit of effort was high, ranging from 18.6 to 25.0 with an average of 23.3.

Table 9. Number of walleye caught from Greig Lake on July 12, 1988 by species. Nets used: 260 m total length of various meshes.

| Species | No. caught | % of total | CPUE* |
|---|---|---|---|
| walleye | 65 | 36.5 | 25.0 |
| yellow perch | 67 | 37.6 | 25.8 |
| white sucker | 33 | 18.5 | 12.7 |
| lake whitefish | 1 | 0.6 | 0.4 |
| total | 178 | 99.9 | 68.5 |

*4Catch Per Unit Effort: catch·(100 m net-day)$^{-1}$.

Table 10. Number of fish caught from Greig Lake on October 13 & 14, 1988 by species. Nets used: 2.5 cm mesh, 145 m total length.

| Species | No. caught | % of total | CPUE* |
|---|---|---|---|
| walleye | 54 | 32.1 | 18.6 |
| yellow perch | 93 | 55.4 | 32.1 |
| northern pike | 15 | 8.9 | 5.2 |
| burbot | 4 | 2.4 | 1.4 |
| cisco | 2 | 1.2 | 0.7 |
| total | 168 | 100.0 | 58.0 |

*Catch Per Unit Effort: catch·(100 m net-day)$^{-1}$

Table 11. Number of fish caught from Greig Lake on August 1 & 4, 1989 by species. Nets used: 2.5 cm mesh, 108 m total length.

| Species | No. caught | % of total | CPUE* |
|---|---|---|---|
| walleye | 57 | 13.9 | 26.4 |
| yellow perch | 333 | 81.4 | 154.2 |
| cisco | 13 | 3.2 | 6.0 |
| northern pike | 5 | 1.2 | 2.3 |
| white sucker | 1 | 0.3 | 0.5 |
| total | 409 | 100.0 | 189.4 |

**Catch Per Unit Effort: catch·(100 m net-day)$^{-1}$.*

On May 23, 1990, a 10 m gang of 5.1 cm mesh and a 20 m gang of 3.8 cm mesh gill nets were set in the north-central area of the lake in a depth of 20 m. Overnight catch included 5 walleye, 1 northern pike and numerous yellow perch (number not determined). The catch per unit effort for walleye was 16.7.

### 5.2.2 Size Distribution and Relative Weights

The walleye caught from Greig Lake between 1988 and 1990 cover a wide size range. Fork lengths ranged from 117 mm to 573 mm with a mean of 315 (N=176), a median of 283 mm and a mode of 225 mm. Length frequency distributions of the samples taken on three occasions all show four discrete size groups, corresponding to four different year classes (Fig. 8).

Both total and fork lengths were recorded from 84 walleye ranging from 117 to 525 mm in fork lengths and 124 to

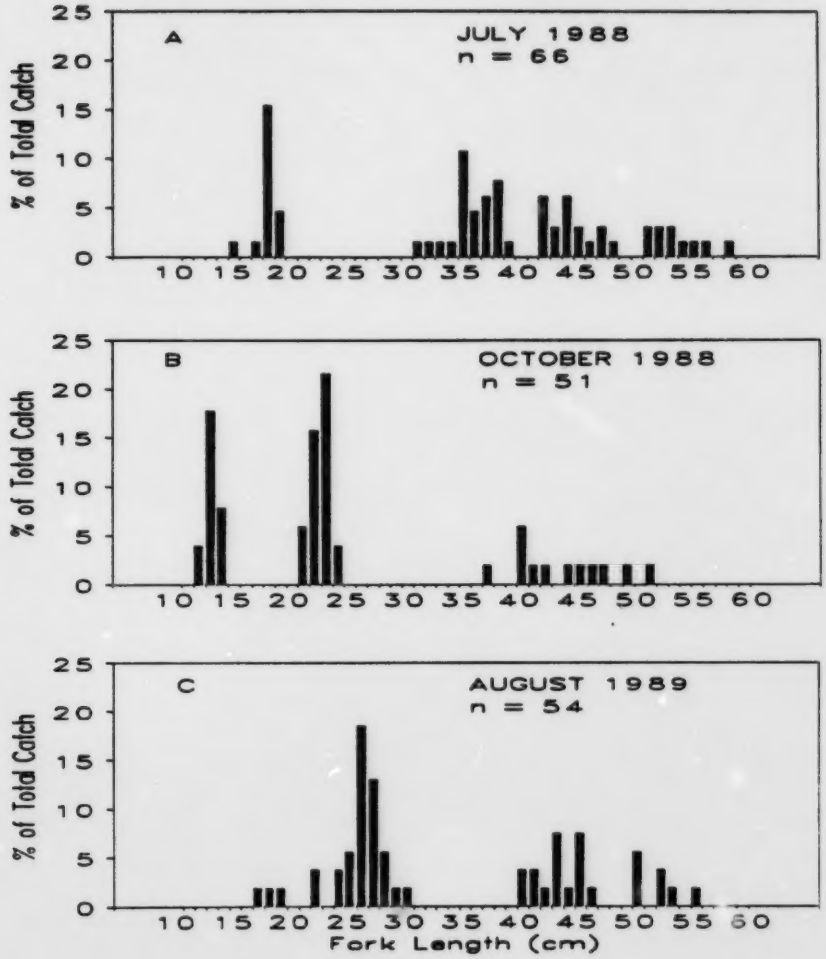


Fig. 8. Length frequency distributions of walleye in Greig Lake in 1988 (graphs A and B) and 1989 (graph C), showing discrete size groups corresponding to the years of fingerling stocking. n=sample size.

555 mm in total lengths. The regression equation derived from these data is as follows: TL=2.209+1.052 FL ($R^2$=1.000, standard error of estimate = 2.227).

Weights of the walleye varied between 17 g and 2,400 g (N=149) with an average of 522 g, a median of 250 g and a mode of 50 g. The weight-length relationship is presented in Fig. 9.

Relative weights of the walleye from Greig Lake ranged from 51 to 105 with an average of 86 and a median of 87 (Fig. 10).

5.2.3 Age Composition, Growth and Size at Maturity

Results of ageing with scales and otoliths are identical. Therefore, either one can be used for growth analysis.

Five age classes (0 to 5 with age 2 missing) were present in the 1988 samples, whereas four classes (1 to 5 with age 3 missing) were found in the samples taken in 1989. Only 5 specimens were collected on May 24, 1990; they were all 3 years old. One year class (1986) was missing from all catches. All specimens taken on July 14, 1988, and August 1/4, 1989, were aged. Their age compositions are shown in Fig. 11.

Detailed growth data by year class are presented in Appendix 3. Growth for those fingerlings stocked in 1987 and 1988 are presented in Fig. 12 to show seasonal growth patterns

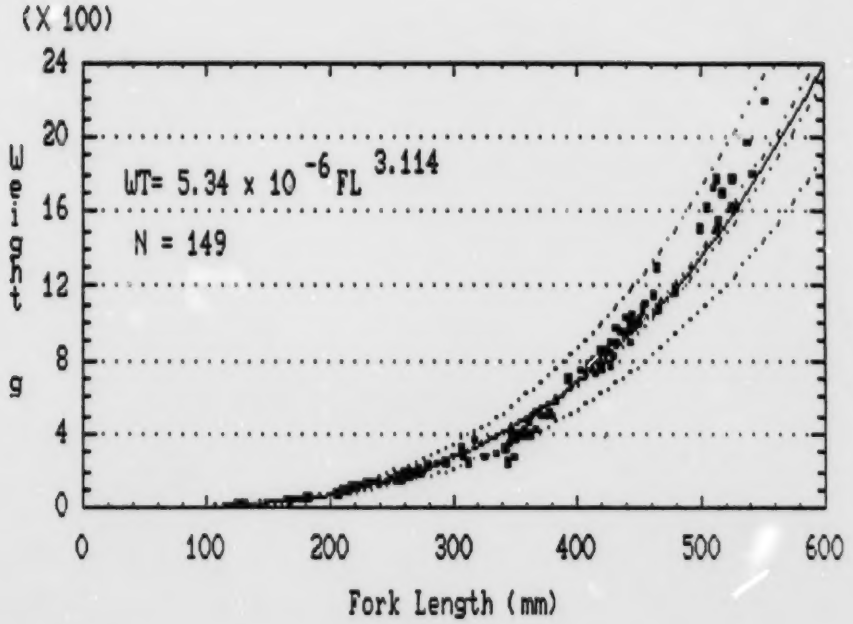


Fig. 9. Weight-length relationship of walleye in Greig Lake in 1988-90. Outer and inner dotted lines indicate 95% confidence limits of predicted values and means, respectively.

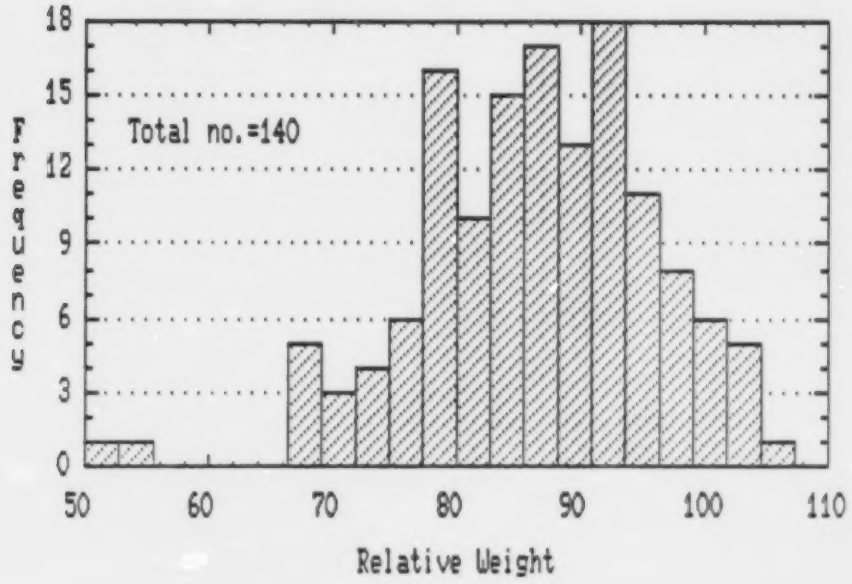


Fig. 10. Relative weights of walleye in Greig Lake in 1988-90.

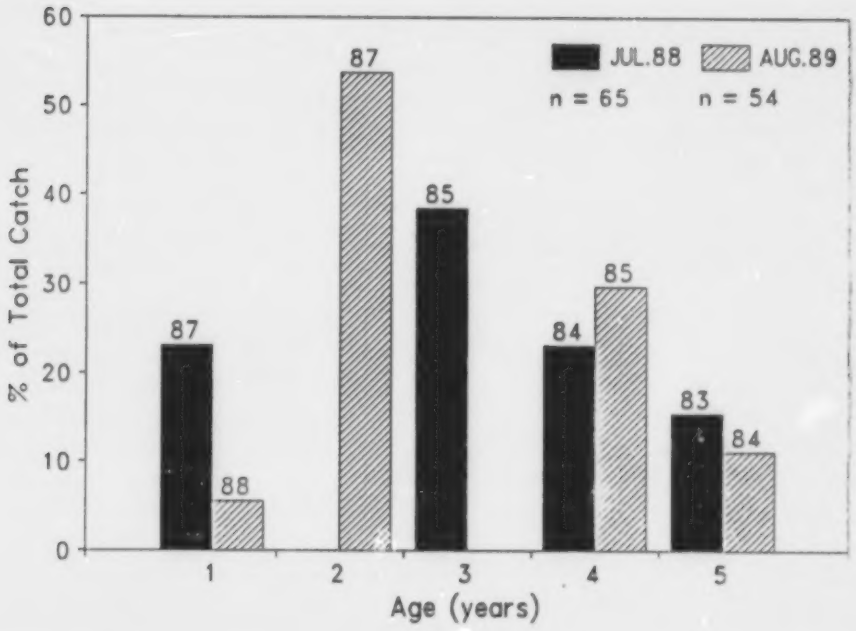


Fig. 11. Age compositions of walleye in Greig Lake in 1988 and 1989 for the year classes 1987 and 1988. Numbers above bars indicate year classes.

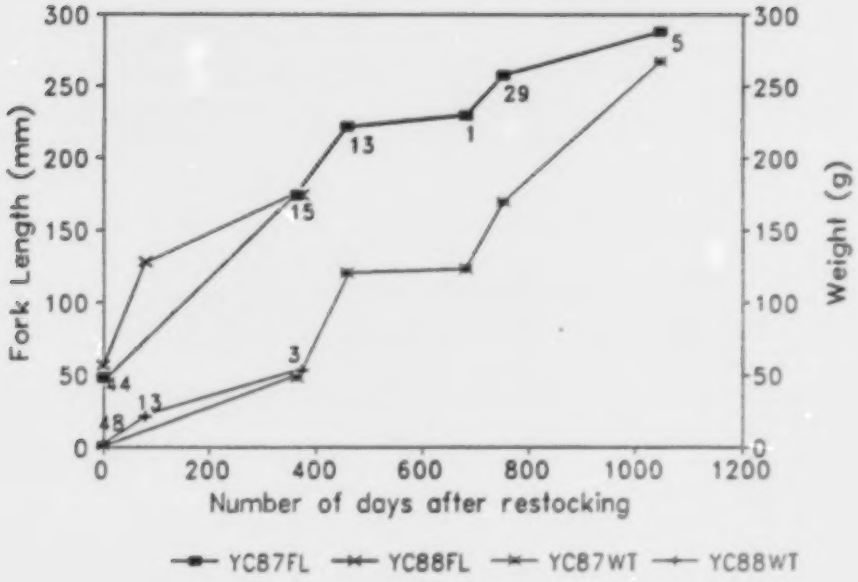


**Fig. 12. Growth of walleye of the year classes 1987 and 1989 in Greig Lake. Measurements taken between 1988 and 1990. Numbers below length data are sample sizes for the 1987 year class, and numbers above the weight data points are sample sizes for the 1988 year class.**

similar to that of the stocked walleye in Smuts Lake (Liaw 1989). The 1988 planting gained 71 mm in fork length and 18.4 g in weight in 79 days after stocking, a daily gain of 0.9 mm in length and 0.23 g in weight. Judging from the growth curve of the 1988 year class, growth after stocking was fast, but almost stopped in the fall. The maximum size gained at the end of the first growing season in the lake was probably about 130 mm in fork length, or 21 g in weight.

Average size-at-age based on measurements in July and August for all year classes are best fitted to the logistic function (Figs. 13 & 14). These growth curves suggest that growth of the stocked walleye in the lake is fast: 95% of the asymptotic size (671 mm, or 3.5 kg) would be reached in 8 years. The average sizes-at-age for the young-of-the-year fish predicted from the growth curves are 113 mm for length and 23.25 g for weight, which are very close to the actual measurements taken in October for the 1988 year class (Fig. 12).

The increase in weight gain starting at age three is due largely to a rapid development of gonads. Conditions of gonads indicate that the size at maturity is around 44 cm in fork length for both sexes. Most of these fish are 4 years old.

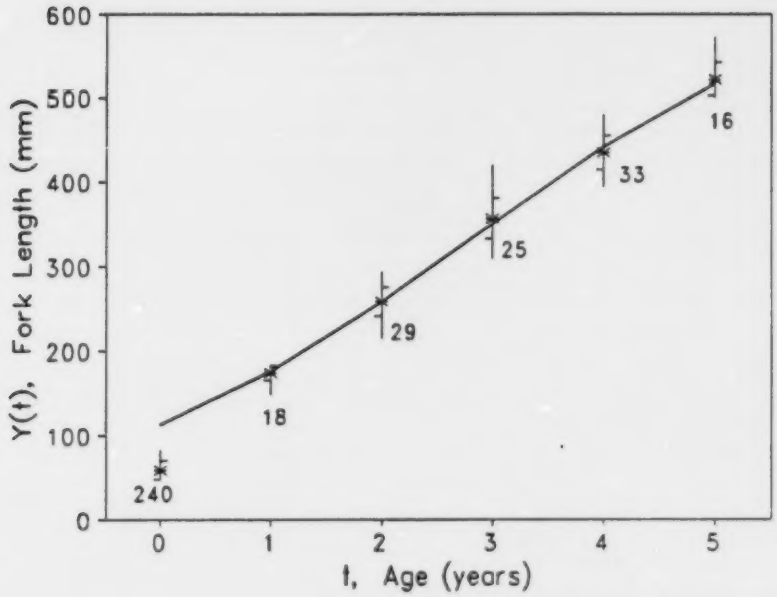


Fig. 13. Average length-at-age (indicated by *) of walleye in Greig Lake in 1988-90. Data points fitted to the logistic growth curve:

$$Y_{(t)}=K/(1+((K-Y_0)/Y_0)(\exp(-rt))),$$

where K=671 mm, $Y_0$=113 mm and r=0.562. The data of age 0 year fish represent only sizes of the fingerlings when stocked, and therefore were not included in calculation of the growth curve. Range and mean±1 SD are indicated by a vertical bar and its tick marks, respectively. Numbers are sample sizes.

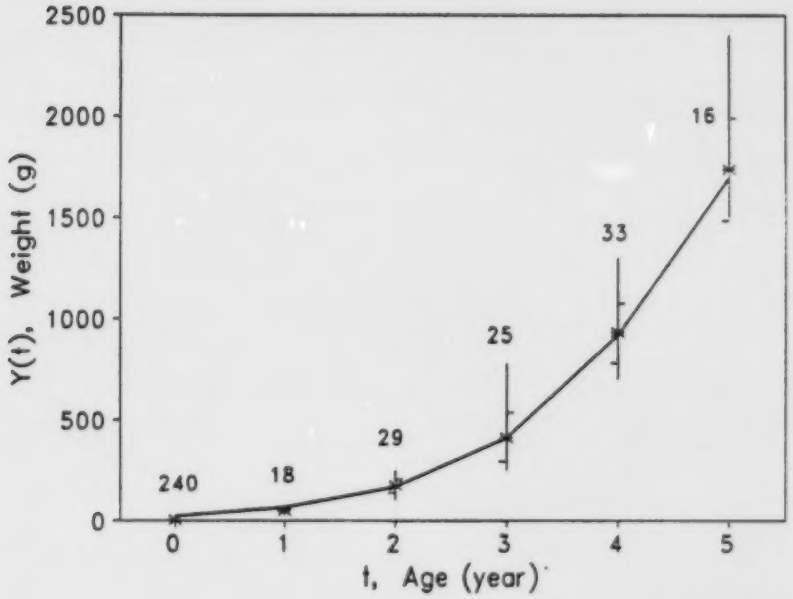


Fig. 14. Average weight-at-age (indicated *) of walleye in Greig Lake in 1988-90. Data points fitted to the logistic growth curve:

$$Y_{(t)}=K/(1+((K-Y_0)/Y_0)(\exp(-rt))),$$

where K=3546 g, $Y_0$=23.25 g and r=0.562. The data of 0 year old fish represent only sizes of the fingerlings when stocked, and therefore were not included in calculation of the growth curve. Range and mean±1 SD are indicated by a vertical bar and its tick marks, respectively. Numbers are sample sizes.

### 5.2.4 Survival and Mortality Rates

Since unequal numbers of fingerlings were stocked each year, catch curves derived from the age composition data (Fig. 11) are inadequate for estimating total instantaneous mortality of the population. However, relative abundance figures (assuming they can be approximated by the age composition data) are available for the same year classes (1984 and 1985) for two consecutive years and can be used to estimate survival rates.

The results of the calculation indicate that the survival between ages 3 and 4 for the 1985 planting was 0.79 and that from age 4 to age 5 for the 1984 year class was 0.48. The two rates average 0.64. The corresponding total instantaneous mortality rates ($Z=- \log_e S$) are 0.24, 0.73 and 0.45. Survival rates for ages 1 to 3 cannot be estimated from the present data. However, judging from the testnetting results, an overall annual survival rate of 64% up to age 4 seems reasonable.

Instantaneous natural mortality rate (M) is estimated to be 0.44 from the growth parameters ($L_\infty$=67.1 cm and K=0.562, K and r respectively in Fig. 13) and an average annual water temperature of 5° C (see section 5.1.4). With a total instantaneous mortality rate of 0.45, this leaves a very small instantaneous fishing mortality of 0.01 (0.45-0.44=0.01), which translates into an exploitation rate of only 0.008.

## 5.3 TURTLE LAKE

### 5.3.1 The Catch

Summary of sets, number of fish caught by mesh size and species from test netting are presented in Appendix 4. White sucker was the most abundant large fish in Turtle Lake, followed closely by the cisco (Table 12). Walleye accounting for 19.4 % of the total standard gang catch, was the third abundant fish species in the lake. Most walleye were caught in the south end of the lake off Kopp's Beach (Appendix 4). Northern pike, the primary angling species, was the fourth most abundant large fish in the lake.

Table 12. Total number of fish caught in six standard gang net sets in Turtle Lake in the summer of 1990, along with percent composition and catch per unit effort by species.

| Species | No. caught | % of total | CPUE* |
|---|---|---|---|
| walleye | 160 | 19.4 | 9.7 |
| white sucker | 217 | 26.4 | 13.1 |
| cisco | 207 | 25.2 | 12.5 |
| northern pike | 139 | 16.9 | 8.4 |
| lake whitefish | 94 | 11.4 | 5.7 |
| yellow perch | 6 | 0.7 | 0.4 |
| total | 823 | 100.0 | 49.8 |

**Catch Per Unit Effort: catch·(100 m net-day)$^{-1}$*

Cisco and white sucker were most abundant in the catch of the shorter standard gangs (Table 13), whereas the short 5.1 cm mesh net caught relatively more whitefish and northern pike (Table 14). Both nets caught far fewer walleye than did the full standard gang nets. However, differences in catches were probably caused mainly by differences in netset location rather than in the length of nets used.

Table 13. Total number of fish caught in four partial (240 m total length) standard gang nets in Turtle Lake in the summer of 1990, as well as per cent composition and catch per unit effort by species.

| Species | No. caught | % of total | CPUE* |
|---|---|---|---|
| walleye | 2 | 1.4 | 0.8 |
| cisco | 68 | 47.5 | 28.3 |
| white sucker | 44 | 30.8 | 18.3 |
| northern pike | 20 | 14.0 | 8.3 |
| lake whitefish | 8 | 5.6 | 3.3 |
| burbot | 1 | 0.7 | 0.4 |
| total | 143 | 100.0 | 59.4 |

**Catch Per Unit Effort: catch·(100 m net-day)$^{-1}$*

The catch of the shorter standard gangs (Table 13) compares more closely to the catches of previous sport fish surveys in which similar nets were used. According to Dunn (1986), ranges of the CPUE by species for the 1973, 1976, 1979 and 1985 sport fish surveys are as follows: walleye, <1-3; white sucker, 11-17; cisco, 19-55; northern pike, 3-11; lake whitefish, <1-4; yellow perch, <1-5 and total, 48-83.

Table 14. Total number of fish caught in four 20 m 5.1 cm mesh net sets in Turtle Lake in the summer of 1990, as well as per cent composition and catch per unit effort by species.

| Species | No. caught | % of total | CPUE* |
|---|---|---|---|
| walleye | 4 | 14.3 | 5.0 |
| northern pike | 12 | 42.8 | 15.0 |
| lake whitefish | 11 | 39.3 | 13.8 |
| white sucker | 1 | 3.6 | 1.2 |
| total | 28 | 100.0 | 35.0 |

**Catch Per Unit Effort: catch·(100 m net-day)$^{-1}$*

### 5.3.2 Size Distribution and Relative Weights

Fork lengths of the walleye (n=167) caught from Turtle Lake in all test nets during 1990 ranged from 159 to 651 mm with an average of 346 mm and a median of 375 mm (Fig. 15). These fish weighed between 40 and 2,900 g with a mean of 584 g and a median of 575 g (Fig. 16). By comparison, catch (n=47) of the 1964-65 standard gangs consisted mainly of larger individuals, ranging from 373 to 599 mm in fork length and 624 to 2,551 g in weight. The average fork length and weight of the 1964-65 catch were 461 mm and 1,298 g, considerably larger than the 1990 averages.

The relationship between lengths and weights for the 1990 catch is shown in Fig. 17. Relative weights calculated from both the 1990 and 1964-65 samples are presented in Fig. 18. The 1990 sample has a mean relative weight of 90 with a standard deviation of 10, whereas the 1964-65 sample has a mean of 101 with a standard deviation of 7. The two sets of relative weights differ significantly ($p=0.05$).

Both total and fork length measurements are available for 165 walleye sampled in 1990. These fish ranged from 159 to 651 mm in fork length and 169 to 681 mm in total length. The regression equation derived from these data is as follows: $TL=-0.500+1.061\ FL$ ($R^2=0.996$, standard error of estimate =9.473).

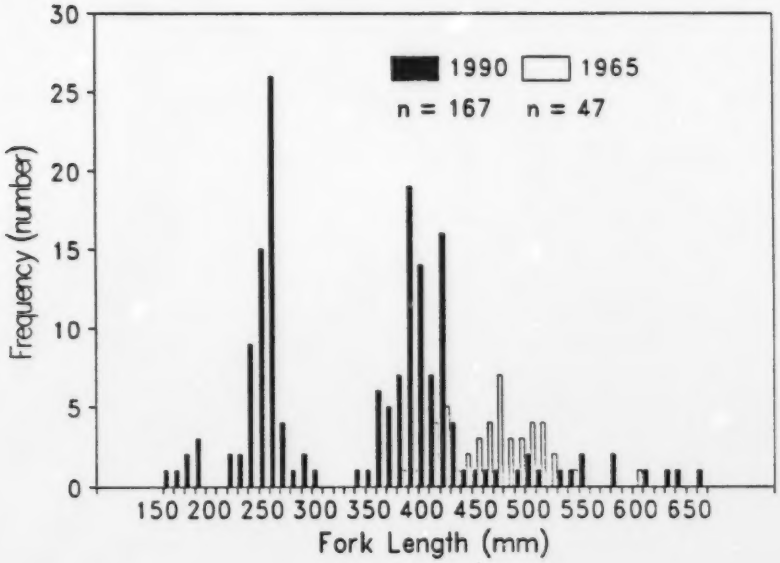


Fig. 15. Length frequency distribution of walleye in Turtle Lake in 1965 and 1990.

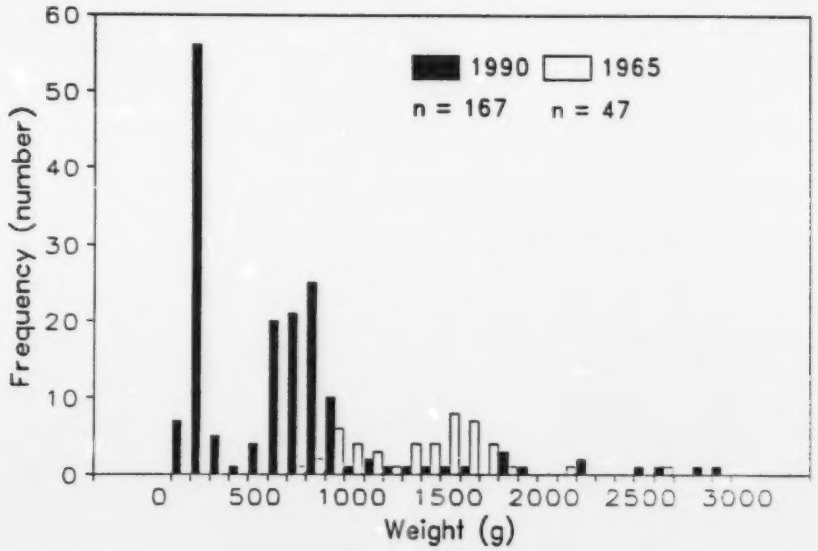


Fig. 16. Weight frequency distribution of walleye in Turtle Lake in 1965 and 1990.

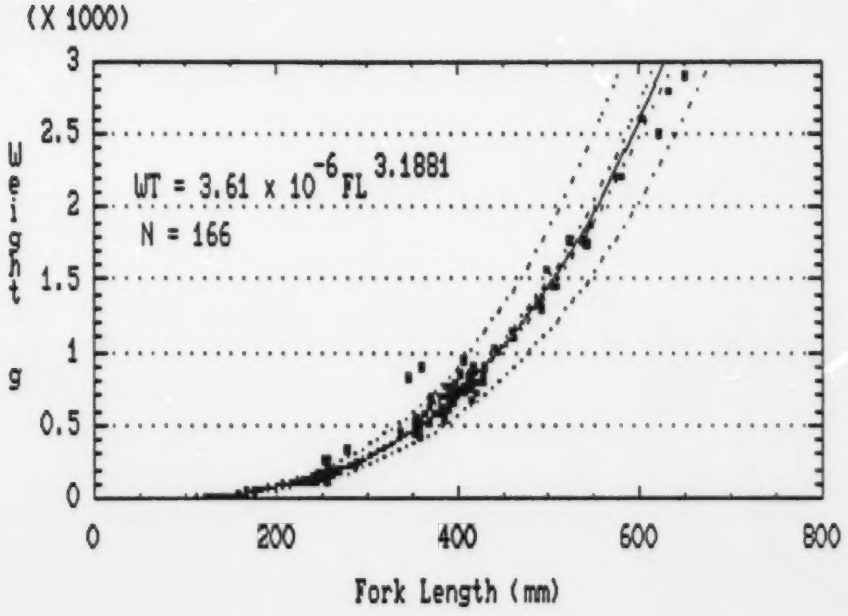


Fig. 17. Weight-length relationship of walleye in Turtle Lake in 1990. Outer and inner dotted lines indicate 95% confidence limits of predicted values and means, respectively.

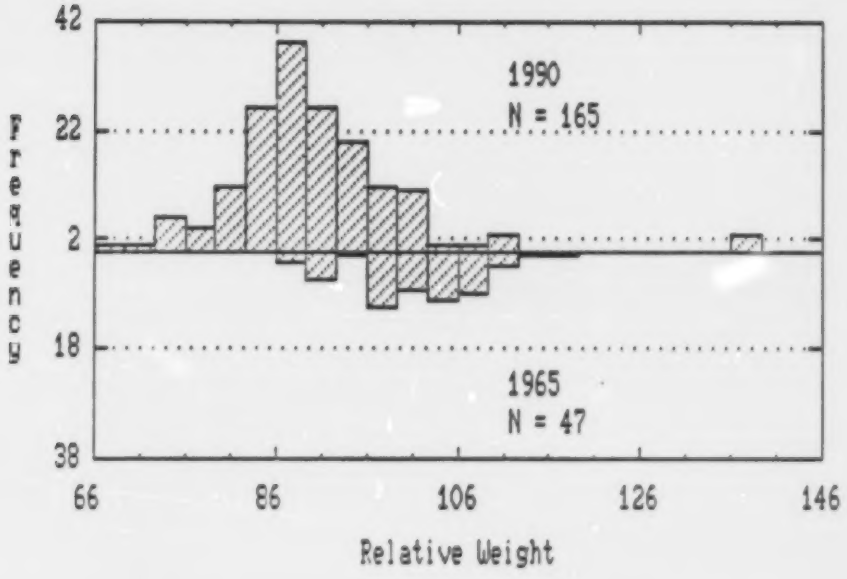


Fig. 18. Relative weights of walleye in Turtle Lake. A comparison of the 1990 and the 1965 data.

### 5.3.3 Age Composition, Growth and Size at Maturity

Ages determined from otoliths are used in the analysis of growth. Ages determined from scales are nearly identical to those determined from otoliths within the age range.

Nine age groups or year classes (ages 1 to 10 with age 8 missing) were identified from the sample (n=151) of walleye aged. The number of fish and per cent of total in each age group or year class are presented in Table 15. The data suggest the presence of two strong year classes (1986 and 1988), together making up 84.1% of all the walleye aged.

Table 15. Age composition of walleye caught in Turtle Lake, summer 1990.

| Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Year Class | 89 | 88 | 87 | 86 | 85 | 84 | 83 | 82 | 80 | 79 |
| Number | 7 | 62 | 3 | 65 | 3 | 5 | 1 | 0 | 2 | 3 |
| % of total | 4.6 | 41.1 | 2.0 | 43.0 | 2.0 | 3.3 | 0.7 | 0 | 1.3 | 2.0 |

Size-at-age data are fitted to the von Bertalanffy growth function for fork lengths (Fig. 19) and to the Gompertz function for weights (Fig. 20). The asymptotic fork length and weight for the population based on 1990 catch are 736 mm and 3,080 g, respectively. The maximum age (the age at which 95% of the asymptotic size is reached) calculated from the asymptotic fork length is 15.6 years. In Fig. 19, a von Bertalanffy growth curve for the 1964-65 data is also

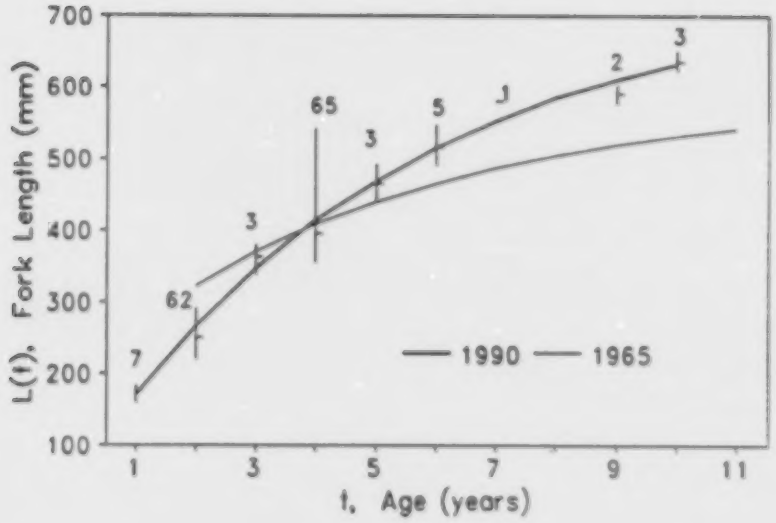


Fig. 19. Average length-at-age of walleye in Turtle Lake fitted to the von Bertalanffy growth curve:

$$L_{(t)}=L_{\infty}(1-\exp(-K(t-t_0)))$$

where $L_{\infty}$=736 mm, K=0.188 and $t_0$=-0.3836 for the 1990 data and $L_{\infty}$=586 mm, K=0.1953 and $t_0$=-2.074 for the 1965 data. Vertical bars indicate range, tick marks on bars indicate averages and numbers above bars are sample sizes for the 1990 data. For the 1965 data, only the growth curve is shown.

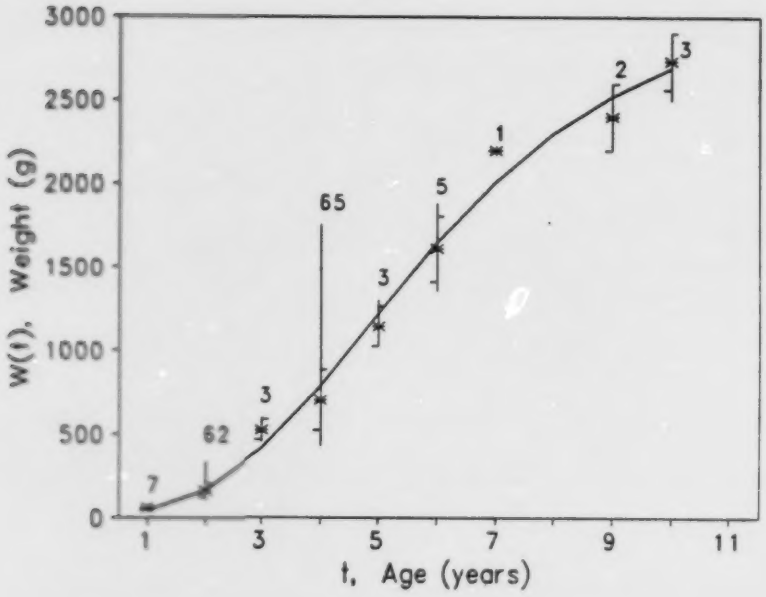


Fig. 20. Average weight-at-age (indicated by *) of walleye in Turtle Lake in 1990. Data points fitted to the Gompertz growth curve:

$$W_{(t)}=W_0 * \exp(G(1-\exp(-gt))),$$

where $W_0$=5.081 g, G=6.407 and g=0.3866. $W_\infty=W_0 * \exp G$= 3080 g. Range and mean±1SD are indicated by vertical bars and their tick marks, respectively. Numbers are sample sizes.

presented for comparison. The growth curves indicate that walleye older than age 4 years in Turtle Lake grow to a larger size-at-age now than in the past. The asymptotic fork length and maximum age based on the 1964-65 data are 586 mm and 13.3 years, respectively.

Field examinations of gonads suggest male Turtle Lake walleye mature at about 370 mm fork length and females at 390 mm. These fish are between 3 and 4 years of age.

### 5.3.4 Survival and Mortality Rates

A catch curve derived from the age composition data (Table 15) is inadequate for estimating total instantaneous mortality of the walleye population in Turtle Lake, because year class strength appears to be largely dictated by the number of fry/fingerlings stocked (see Sec. 6.2.3). However, an instantaneous natural mortality rate of 0.21 may be estimated from the von Bertalanffy growth parameters ($L_{\infty}$=73.6 cm and K =0.1888, Fig. 19) and the annual average surface water temperature of 5° C.

Thus, although total instantaneous mortality rate for the walleye in Turtle Lake cannot be directly estimated from the catch curve, it can be indirectly approximated if the instantaneous fishing mortality rate (F) is known. The rate of instantaneous fishing mortality for Delaronde Lake walleye has been estimated to be 0.44. Thus, by assuming that the same rate applies to Turtle Lake walleye, the total instantaneous

mortality rate for Turtle Lake walleye can be calculated as Z=M+F = 0.21 + 0.44 = 0.63. This translates into an annual survival rate of 53% or an annual mortality rate of 47%. From these parameters, the annual rate of exploitation can be estimated as u = FxA/Z = 0.33, or 33%.

## 6. DISCUSSION

### 6.1 POPULATION ABUNDANCE

Without information from extensive mark and recapture studies, walleye population abundance in the study lakes can only be approximated indirectly. Some idea of the relative abundance can be obtained by comparing CPUE data from experimental fishing. The CPUEs for walleye were 25.0, 9.7 and 2.8 in Greig, Turtle and Delaronde Lakes, respectively. These numbers can be compared to CPUE data from lakes which are known to have good walleye populations. For example, the CPUE for walleye in Limestone Lake was 44.9 in the 1989 survey (Gloutney 1991); in Ballantyne Bay of Deschambault Lake, the CPUEs for walleye were 40.1 in 1962 (Johnson 1967) and 29.3 in 1991 (Liaw, unpublished data) and that in Pinehouse Lake was 17.6 in 1986 (Liaw 1988). Thus, using these figures as a benchmark for comparison, walleye abundance in the three study lakes may be rated as excellent in Greig, fair in Turtle and poor in Delaronde.

As established earlier, walleye in Greig Lake are all from stocking. Therefore, by knowing the average annual

survival rate (0.64), the number of stocked walleye surviving in each year after stocking can be calculated. Table 16 shows the number of fingerlings stocked and the number of walleye surviving in each year class in four different years. The total number of walleye surviving, as well as the number surviving per hectare of water area to the year 2000 are illustrated in Fig. 21.

Table 16. Numbers of walleye fingerlings stocked in Greig Lake from 1982 to 1989 and estimated numbers surviving in four different years. Estimates of survival based on an average annual survival rate of 64%.

| Year Class | Number stocked | | Estimated number surviving in | | | |
|---|---|---|---|---|---|---|
| | Total | $ha^{-1}$ | 1988 | 1989 | 1990 | 2000 |
| 1982 | 284 | 0.175 | 20 | 13 | 8 | 0 |
| 1983 | 1,000 | 0.617 | 107 | 69 | 44 | 1 |
| 1984 | 1,900 | 1.173 | 319 | 204 | 131 | 1 |
| 1985 | 7,500 | 4.630 | 1,966 | 1,258 | 805 | 9 |
| 1986 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1987 | 97,200 | 60 | 62,208 | 39,813 | 25,480 | 294 |
| 1988 | 9,500 | 5.864 | 9,500 | 6,080 | 3,891 | 45 |
| 1989 | 6,200 | 3.827 | 0 | 5,200 | 3,968 | 45 |
| Total | 123,584 | | 74,120 | 52,637 | 34,327 | 395 |
| No·$ha^{-1}$ | | 76.286 | 45.753 | 32.492 | 21.190 | 0.244 |

The unique situation in Greig Lake offers an opportunity to relate CPUE data to the density of walleye in the study lakes. Using the data obtained in 1988, one CPUE is

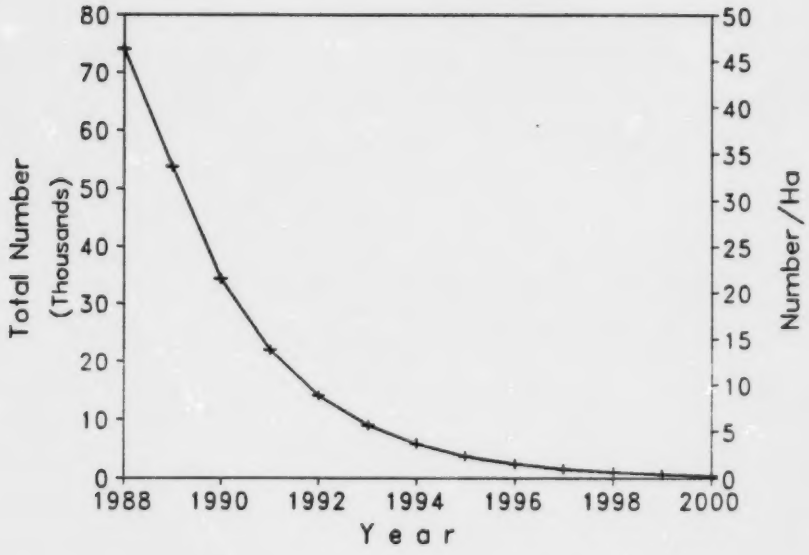


Fig. 21. Survival of stocked walleye in Greig Lake projected to the year 2000, assuming an overall annual survival rate of 64%. Data are expressed both in terms of total number surviving and number surviving per hectare of water surface regardless of depth zones.

equivalent to 1.83 (=45.7/25) walleye per ha of water surface in Greig Lake. Note that the estimated walleye standing crop does not include young-of-the-year and the majority of one year old fish. These young walleye are usually less vulnerable to the test nets used.

The fish density equivalence of one CPUE for predominantly 2 years and older walleye obtained from Greig Lake (1.83 fish $\cdot$ ha$^{-1}$) can then be used to estimate the standing crop of walleye in other lakes where similar CPUE data are available (Table 17). However, it should be realized that the estimates can only be considered as crude approximations. Differences in water area and morphometry among lakes, as well as in the manner and timing of fishing are some of the potential sources of error involved in such extrapolation.

Table 17. Walleye standing crops in four Saskatchewan lakes extrapolated from Greig Lake 1988 CPUE and population density data.

| Lake | Area (ha) | Year | CPUE | Walleye standing crop | | |
|---|---|---|---|---|---|---|
| | | | | no$\cdot$ha$^{-1}$ | kg$\cdot$ha$^{-1}$ | Total no. |
| Greig | 1,620 | 1988 | 25.0 | 45.70 | 23.9 | 74,120 |
| | | 1966 | 0.6 | 1.10 | 2.8 | 1,780 |
| Pinehouse | 36,500 | 1986 | 17.6 | 32.21 | 22.1 | 1,175,670 |
| Turtle | 6,400 | 1990 | 9.7 | 17.75 | 10.4 | 113,610 |
| | | 1964/5 | 1.2 | 2.20 | 2.8 | 14,080 |
| Delaronde | 8,570 | 1990 | 2.8 | 5.12 | 3.9 | 43,910 |
| | | 1975 | 2.1 | 3.84 | 2.2 | 32,910 |

It is clear from Table 17 that walleye populations in all the three lakes under study have improved since the last survey. The tremendous increase in walleye abundance in Greig Lake is entirely due to recent fingerling stockings. The eight-fold increase in the standing crop of walleye in Turtle Lake is also undoubtedly due to recent stocking of fry and fingerlings.

Walleye population in Delaronde Lake has also improved since the 1975 survey. But the 1.3-fold increase in standing crop is small compared to that in the other two lakes. This is probably due to the fact that relatively small numbers of fingerlings have been stocked in this lake. Further, natural reproduction has apparently not been very successful in producing large numbers of recruits to the population.

Note that standing crop is not the same as annual production. The latter is usually much smaller than the former and its percentage as the standing crop may vary with lakes. For example, the long-term (1941-86) average annual commercial fishing production of walleye in Pinehouse Lake was 0.97 $kg \cdot ha^{-1}$, only about 4.4% of the estimated standing crop. In Blue Lake, Manitoba an annual production of 2.1 $kg \cdot ha^{-1}$ was estimated from a mean annual standing crop of 6.1 $kg \cdot ha^{-1}$. In Clear Lake, Iowa annual production fluctuated from 1.23 to 9.71 $kg \cdot ha^{-1}$ with standing crops ranging from 2.63 to 16.53

$kg \cdot ha^{-1}$ (data from Colby et al. 1979).

## 6.2 ASSESSMENT OF STOCKING SUCCESS

### 6.2.1 Delaronde Lake

One of the walleye fingerlings finclipped and released in 1984 was recaptured in the 1990 test netting. While this information offers direct evidence of the survival of the stocked fingerlings, the contribution of the stocked fingerlings to the population cannot be directly assessed with the present data. In order to be able to do so, all stocked fingerlings must be marked before release or can be identified later by some kind of genetic markers, or handling checks that may be present on the otoliths.

A comparison of fingerling stocking records (Table 2) and year-class composition in testnet catches (Table 8) suggests that the strong 1984 and 1985 year classes may be attributable to the stocking of relatively large numbers of fingerlings in those years. However, the same set of data also suggest that natural reproduction may contribute significantly to the strength of year classes as well. In fact, the strongest year class (1986) is probably primarily due to a more successful natural recruitment, as only a small number of fingerlings were stocked in that year.

The above speculation can be supported by the data presented in Table 18. The contribution of stocked fingerlings to year-class abundance was calculated on the basis of the

standing crop in each year class (age composition x total standing crop) and the number of stocked fingerlings surviving in 1990 (assuming an average annual survival rate of 44%, see Section 5.1.4).

Table 18. Estimates of % contribution of stocked fingerlings to year-class abundance of walleye in Delaronde Lake in 1990.

| Age | Year class | Standing crop (no.) | Number stocked | Number surviving | per cent contribution from stocked fingerlings |
|---|---|---|---|---|---|
| 2 | 1988 | 878 | 80 | 15 | 1.8 |
| 3 | 1987 | 3,601 | 0 | 0 | 0.0 |
| 4 | 1986 | 25,117 | 3,660 | 137 | 0.5 |
| 5 | 1985 | 5,357 | 30,000 | 495 | 9.2 |
| 6 | 1984 | 4,479 | 160,590 | 1,165 | 26.0 |
| 7 | 1983 | 1,800 | 2,900 | 9 | 0.5 |
| 8 | 1982 | 878 | 1,500 | 2 | 0.2 |
| 9 | 1981 | 1,800 | 440 | 0 | 0.0 |
| Total | | 43,910 | 199,170 | 1,823 | 4.15* |

**total no. surviving/total standing crop x 100*

The above assessment leads to the conclusion that undoubtedly some stocked walleye survived, but the number stocked is too small to make a significant impact on the walleye population. Walleye population in Delaronde Lake still depends largely on natural recruitment, which apparently has not been very large. The data also indicate that in order to greatly enhance the walleye population in this lake, stocking rate must be increased to at least the level of 1984, which is

about 19 fingerlings·ha$^{-1}$, or about 163,000 fingerlings total per year.

6.2.2 Greig Lake

Excellent results of test netting during 1988-89 and recapture of previously finclipped fish provide convincing evidence that stocking of walleye fingerlings has been successful in Greig Lake. Four discrete size groups are present in the catches of the test nets (Fig. 8). The year classes to which these groups belong correspond to the years fingerlings were stocked (Table 4). No fish belonging to the 1986 year class were captured, as no stocking was done in that year. Furthermore, year-class strength (Fig. 11) appears to be correlated with the number of fingerlings stocked: close to 100,000 fingerlings were stocked in 1987, resulting in the strongest year class. All evidence indicates clearly that all walleye in Greig Lake probably originated from stocking, and little or no natural reproduction has yet occurred.

Results of previous test netting (Lane 1967; Wallin 1985) suggest that fry stocking conducted in the past (Table 3) had not been successful. Thus, it appears that in Greig Lake, fingerling stocking is more effective than fry stocking in establishing a good walleye population.

6.2.3 Turtle Lake

Walleye stocking records (Tables 5 & 6) and age composition of the 1990 testnetting catch (Table 15) are combined in Fig. 22 to show the relationship between stocking

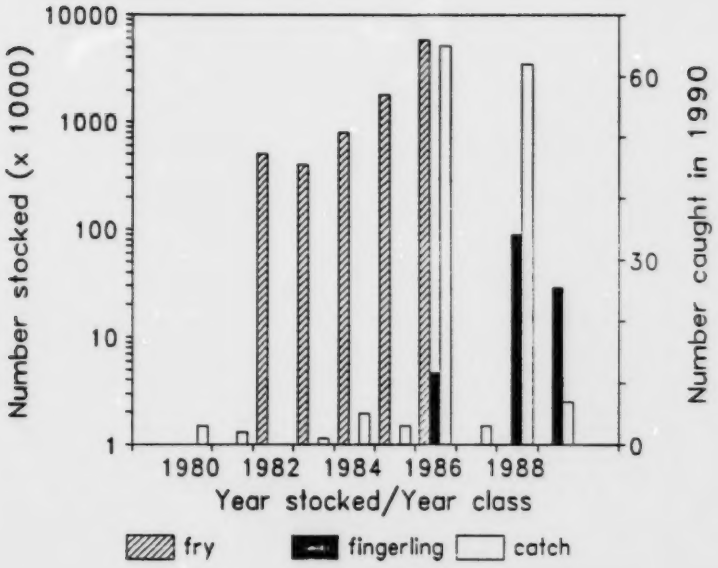


Fig. 22. Numbers of walleye caught in test nets in 1990 by year class compared with numbers of fry/fingerlings stocked each year from 1980 to 1989 in Turtle Lake.

and year-class strength. The data suggest that while fingerling stocking appears to be more successful in producing strong year classes, fry stocking, in greater quantities, may also be successful in Turtle Lake. The strongest year class was produced in 1986 when both fry and fingerlings were stocked, but the contribution to year-class abundance from each method of stocking and natural reproduction can only be speculated. Following the same procedure used for Delaronde Lake (Table 18), the contribution of stocked fingerlings or fry to Turtle Lake walleye can be roughly estimated (Table 19).

Unlike in Greig Lake, the present data suggest that fry and fingerling stockings are probably equally suitable in Turtle Lake, provided large numbers of fry are used. The reason for the difference between the two lakes is not known. But results of a comparative study on fry versus fingerling stockings in Smuts Lake suggest that the availability of suitable zooplankton food sources at time of fry stocking might be a key factor in determining fry stocking success (Liaw 1990). Previous limnological surveys (Lane 1967; Sawchyn 1967) indicated that Turtle Lake produced more plankton than Greig Lake (114 vs 39 $kg \cdot ha^{-1}$ dry wt). Therefore, it is reasonable to assume that there may be more suitable zooplankters as food for newly stocked walleye fry in Turtle Lake than in Greig Lake.

Table 19. Estimates of per cent contribution of stocked walleye to year-class abundance of walleye in Turtle Lake, 1990.

| Age | Year class | Standing crop(no.) | Number stocked | | Number surviving | | % contribution | |
|---|---|---|---|---|---|---|---|---|
| | | | Fingerling | Fry | Fingerling[a] | Fry[b] | Fingerling | Fry |
| 1 | 1989 | 5,681 | 28,640 | 0 | 15,179 | | c | |
| 2 | 1988 | 46,580 | 89,290 | 0 | 25,082 | | 55.9 | |
| 3 | 1987 | 2,272 | 0 | 0 | | | | |
| 4 | 1986 | 48,852 | 4,670 | 5,800,000 | 368 | 26,917[d] | 0.8 | 55.1[d] |
| 5 | 1985 | 2,272 | 0 | 1,800,000 | | 2,139 | | 94.1 |
| 6 | 1984 | 3,408 | 0 | 400,000 | | 247 | | 7.2 |
| 7 | 1983 | 1,136 | 0 | 500,000 | | 32 | | 2.8 |
| 8 | 1982 | 0 | 0 | 0 | | | | |
| 9 | 1981 | 1,136 | 0 | 0 | | | | |
| 10 | 1980 | 2,272 | 0 | 0 | | | | |
| Total | | 113,609 | 122,600 | 8,500,000 | 40,629 | 29,335 | | |

a. Assumes an average annual survival rate of 53%, see Section 5.3.4.
b. Assumes an average annual survival rate of 26 % estimated from the 1986 data (see footnote d below).
c. Over 100% due to underestimate of the standing crop of one year old fish.
d. From the 1988 data, the contribution of natural recruitment to the year-class abundance is 44.1% (=100-55.9). Apply this number to the 1986 year class, the contribution of stocked fry to the year-class abundance is: 100-(0.8+44.1)=55.1%. Therefore, the number of stocked fry surviving in 1990 is 55.1% of 48,852, or 26,917 fish. From this number,the survival of stocked fry to age 4 can be estimated as 26,917/5,800,000=0.0046, which gives an average annual survival rate of 0.26, or 26%.

The estimated average annual survival rate of 26% for stocked fry in Turtle Lake is high compared with the published data. For example, percent survival from stocking to age 3 in West Blue Lake, Manitoba ranged from 0.038 to 0.249% (Schweigert et al 1977), and that in Clear Lake, Iowa ranged from 0 to 0.023% (Carlander & Payne 1977). The average survival from these examples is 0.08%, which is equivalent to an average annual survival of 9.3%, only about 1/3 of that in Turtle Lake.

Knowing the average annual survival rates of stocked fingerlings and fry (53% and 26%), the number of fingerlings or fry required to be stocked to attain a certain level of abundance some years later can be calculated. For example, in order to have 100 walleye surviving in Turtle Lake three years after stocking, 5,690 fry or 635 fingerlings would have to be stocked. Therefore, in Turtle Lake stocking one fingerling is equivalent to stocking about 9 fry (=5,690/635) in terms of survival from stocking to age 3. The average cost of producing one fry at the Fort Qu'Appelle Fish Culture Station is estimated at one tenth of one cent (Rob Kidd, personal communication). The costs of producing one fingerling from the Meadow Lake Ponds vary from year to year depending on numbers of fingerlings produced: in 1989 it was $0.66, but in 1990 it was $0.05. The two years averaged $0.36 per fingerling produced. With these values, the economy of fry versus fingerling stocking can be evaluated. For example, a

management goal of adding 35,000 more three year old walleye to Turtle Lake would require 2,000,000 fry or roughly 222,200 fingerlings. The fry cost $2,000, whereas the fingerlings cost about $80,000 (the average fingerling production cost of $0.36 is used). Even if the least production cost ($0.05) is used, they would cost at least $11,000. Therefore, in Turtle Lake it seems to make more economic sense to stock fry rather than fingerlings.

## 6.3 POPULATION CHARACTERISTICS

Population characteristics such as the instantaneous mortality/survival rate, growth and condition are useful parameters in assessing the performance of stocked fish.

Instantaneous mortality rates estimated for walleye in the three lakes are 0.81, 0.63 and 0.45 for Delaronde, Turtle and Greig, respectively (The corresponding annual survival rates are 44%, 53% and 64%). These rates are within the range normally found for walleye populations, which vary between 0.14 to 1.83 with the common rates ranging from 0.51 to 0.80 (Colby et al. 1979).

The estimated mortality rates indicate that stocked walleye fingerlings survived better in Greig Lake than in Turtle and Delaronde Lakes. This is consistent with the estimated walleye abundances in these lakes. Estimates of natural mortalities suggest that fishing mortalities in Delaronde and Turtle Lakes are higher than in Greig Lake, with

annual rates of exploitation of 30% for Delaronde, 33% for Turtle and only 0.8% for Greig. However, it should be pointed out that these estimates are based on small sample sizes and some unverified assumptions and thus, should only be considered as rough approximations.

The plumpness and physiological well-being of fish can be assessed by condition indices. The traditional approach is to use Fulton-type condition factors (Ricker 1975). But recently relative weight ($W_r$), which is calculated on the basis of a species-wide standard weight ($W_s$), has become more commonly used (Murphy et al. 1991). Fish that have a $W_r$ value of close to 100 might be considered in "optimal" or "better-than-average" condition (Willis et al. 1989).

Of the three lakes under study, walleye populations in Turtle ($W_r$=90) and Delaronde ($W_r$=88) in 1990 had better condition than the population in Greig Lake ($W_r$=86) in 1988-89. Statistically, there is no significant difference in $W_r$ values between Turtle and Delaronde Lakes, and between Delaronde and Greig Lakes, but Turtle Lake walleye were in significantly better condition than those in Greig Lake. This may indicate that walleye in Greig Lake were crowded. By comparison, walleye in Turtle Lake in 1965 had an average $W_r$ value of 101, indicating a sparse population. The low $W_r$ of 82 for walleye in Delaronde Lake in 1975 was not caused by overcrowding as the population was very small. The small $W_r$ may indicate an unfavourable ecological condition. Another

stocked walleye population which is known to have an excellent condition is found in Smuts Lake (Liaw 1989). The average $W_r$ of Smuts Lake walleye was 91. Therefore, for Saskatchewan walleye populations an average $W_r$ of 90, rather than 100 should perhaps be considered as optimal.

The growth of walleye populations in the three lakes are compared with that in Pinehouse, Kenosee and Smuts Lakes (Fig. 23). The latter two lakes represent fast growing populations, while the former represents a slow growing walleye population in Saskatchewan. The growth of walleye in Greig and Turtle are clearly fast, comparing favourably to the fastest growing walleye populations in Saskatchewan. The growth of walleye population in Delaronde Lake is moderate, except for younger fish which are smaller than those in Pinehouse Lake.

Since it is often more difficult to capture young-of-the year walleye in a larger lake, data regarding growth of walleye fingerlings during the first year after stocking are scarce. The measurements from Greig Lake (Fig. 12.) provide some information on the growth of walleye during the first year after stocking. However, a better set of measurements was obtained from Smuts Lake during 1988 (Liaw 1989), which can be used as a benchmark for comparison. These data are fitted to the von Bertalanffy growth function to predict the maximum size attainable at the end of the first growing season after stocking (Figs. 24 & 25).

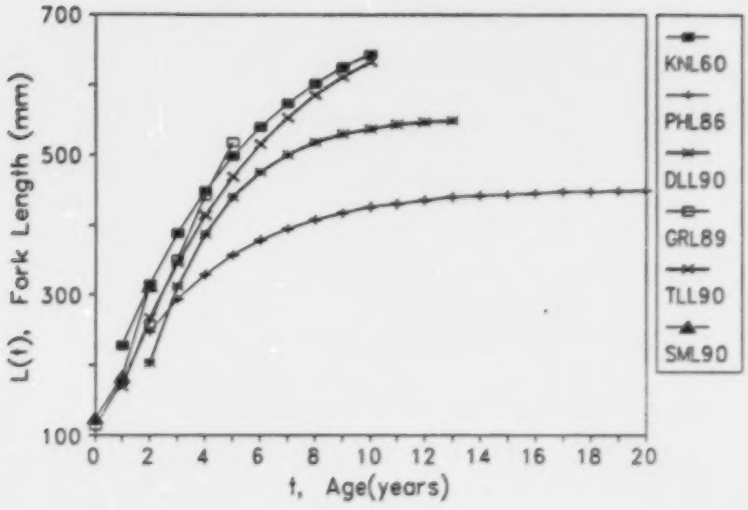


Fig. 23. A comparison of the growth curves of walleye in the three lakes under study with that of a slow (PHL86) and a fast (KNL60) growing natural walleye populations in Saskatchewan. KNL60 - Kenosee L. 1960; PHL86 - Pinehouse L. 1986; DLL90 - Delaronde L. 1990; GRL89 - Greig L. 1988-89; TLL90 - Turtle L. 1990 and SML90 - Smuts L. 1988-90. Data points for Kenosee and Pinehouse Lakes are fitted to the von Bertalanffy growth function:

$$L_{(t)}=L_{\infty}(1-\exp(-K(t-t_0))),$$

where $L_{\infty}$=736 mm, K=0.1899 and $t_0$=-0.9414 for Kenosee L. and $L_{\infty}$=451 mm, K=0.2575 and $t_0$=-1.082 Pinehouse L. Smuts Lake data are actual average length-at-age values (too few data points to fit to a growth function).

The maximum size attainable during the first year of growth is 144 mm (95% of $L_\infty$=152) in fork length, or 25.43 g in weight (95% of $W_\infty$=26.77 g) (the density of walleye in the 47 ha Smuts Lake was estimated at 1,313 fish·ha$^{-1}$). The maximum length is attained in 152 days and the maximum weight is reached in about 109 days after stocking. After this time there is very little increase in size until the beginning of next growing season.

The predicted size at the end of the first growing season for the walleye in Greig Lake (113 mm, or 23.25 g) is close to the maximum size predicted for the walleye in Smuts Lake after the first growing season. This growth rate is good in view of the fact that Greig Lake is more northerly located and is less productive.

In order to provide better protection for game fish, upper size limits have recently been introduced into Saskatchewan's sport fishing regulations. The fitting of growth curves and calculation of maximum sizes (95% of the asymptotic sizes) of walleye populations based on adequate growth measurements provide useful information to assess the effectiveness of the upper size limit set for a walleye population. A sample of $L_\infty$ and $L_{max}$ in fork length for Saskatchewan walleye populations is presented in Table 20.

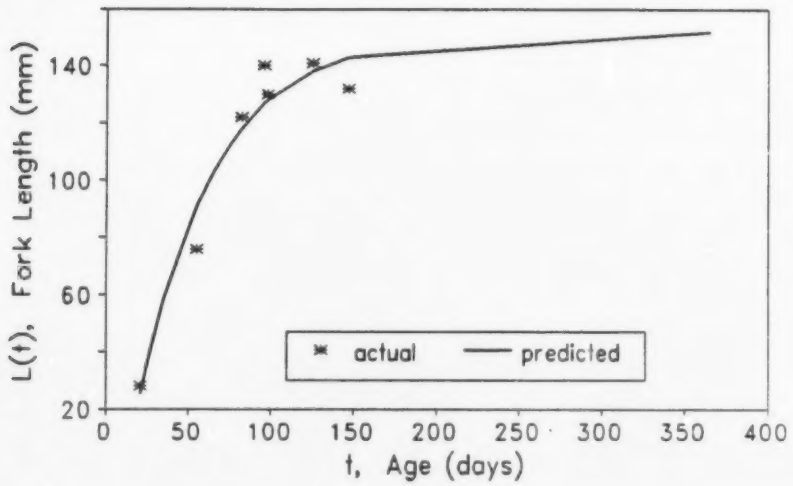


Fig. 24. Growth in fork length of young-of-the year walleye in Smuts Lake in 1988. Data points fitted to the von Bertalanffy growth function:

$$L_{(t)}=L_{\infty}(1-\exp(-K(t-t_0))),$$

where $L_{\infty}$=152 mm, K=0.021 and $t_0$=12.75 days. Fry stocked May 27, 1988.

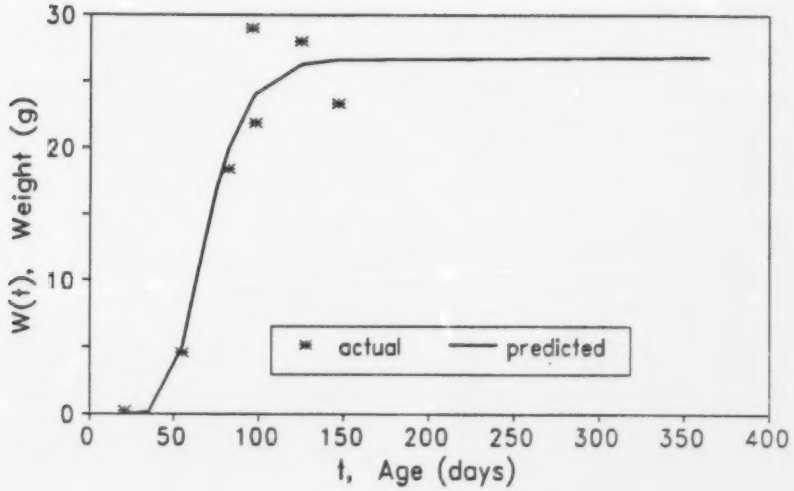


Fig. 25. Growth in weight of young-of-the year walleye in Smuts Lake in 1988.
Data points fitted to the Gompertz growth function:

$$W_{(t)}=W_0*\exp(G(1-\exp(-gt))),$$

where $W_0$=1.767E-24 g, G=0.5798 and g=0.06452, $W_\infty=W_0*\exp G$=26.77 g.

Table 20. Estimated asymptotic ($L_\infty$) and maximum ($L_{max}$) fork lengths for selected walleye populations in Saskatchewan.

| Lake | Year | $L_\infty$ (mm) | $L_{max}$ (mm) |
|---|---|---|---|
| Pinehouse | 1986 | 451 | 428 |
| Four lakes west of Sandy Bay | 1983 | 503 | 478 |
| Buffalo Pound | 1976 | 550 | 522 |
| Delaronde | 1990 | 639 | 607 |
| Greig | 1989 | 671 | 637 |
| Kenosee | 1960 | 736 | 699 |
| Turtle | 1990 | 736 | 699 |
| Lac La Ronge | 1990 | 745 | 708 |
| Tobin | 1979 | 791 | 751 |
| Hunter Bay, Lac La Ronge | 1990 | 986 | 937 |

The current upper size limit for walleye is 600 mm total length (=567 mm fork length*). The data in the above table suggest that this limit may be adequate for most walleye populations in Saskatchewan, but will not protect those whose maximum sizes are below the limit.

*The total length was converted to fork length using the equation, TL (mm)=1.146+1.056 Fl (mm). The regression equation was derived from data pooled from Delaronde, Greig, Turtle and Smuts Lakes with a total sample size of 1,064. $R^2$=0.999 and standard error of estimate =4.401. Ranges for fork and total lengths are 22 mm-651 mm and 23 mm-681 mm, respectively.

# 7. CONCLUSIONS AND RECOMMENDATIONS

Results of the present study indicate that walleye populations in all the three lakes under study have improved recently. The abundance of walleye in Greig Lake has increased 42-fold since the last survey conducted in 1966. There are eight times more walleye in Turtle Lake now than in the mid-1960s. The increase in walleye abundance in Delaronde Lake is less dramatic compared to the other two lakes. There are only 1.3 times more walleye in the lake now than in 1975. Thus, by comparison, walleye abundance can be rated as excellent in Greig, fair in Turtle and poor in Delaronde.

**Greig Lake** - Fry stocking conducted in the past in Greig Lake had not been successful. By contrast, recent fingerling stocking has been very successful in establishing an excellent walleye population in this lake. In fact, walleye has become the most abundant large fish species in the lake. Although some of the stocked walleye have already become sexually mature, natural reproduction in the lake has not occurred due to lack of spawning habitat. Therefore, the walleye population in Greig Lake has to be maintained by regular stocking of fingerlings. If suitable artificial spawning reefs are provided, the walleye may be induced to spawn in the lake and produce natural recruitment to maintain the population in the future.

**Turtle Lake** - The present data suggest that unlike in Greig Lake, fry and fingerling stockings may be equally

successful in Turtle Lake, provided that large numbers (in the order of millions) of fry are used. This is probably because Turtle Lake is more fertile than Greig Lake and provides more suitable zooplankton as food for the newly stocked walleye fry. Turtle Lake has only marginal spawning habitat for walleye. Recruitment from natural reproduction is usually small and unreliable. Therefore, the size of walleye population will always be small if not maintained by stocking. Rough calculations indicate that stocking one fingerling is equivalent to stocking nine fry in terms of survival from stocking to age 3. The cost ratio of fry to fingerling stocking is estimated at 1:40, using the average fingerling production cost from the Meadow Lake Ponds ($0.36 per fingerling). Thus, in Turtle Lake it makes more economic sense to stock fry than fingerlings.

**Delaronde Lake** - While undoubtedly some stocked walleye survived in Delaronde Lake, the number stocked is too small to make a significant impact on the walleye population. The walleye population in this lake still depends largely on natural recruitment, which apparently has been very small since the 1970's. This is probably due to deterioration of spawning habitat in the tributary streams. In order to significantly enhance the walleye population in Delaronde Lake, the annual rate of stocking must be increased to at least 20 fingerlings$\cdot ha^{-1}$, or about 171,000 fingerlings total.

Based on the findings of the present study, the

following management options are recommended:

**A. General recommendations regarding supplemental stocking of walleye in Saskatchewan:**

1. Prior to stocking, factors causing the decline or collapse of the walleye stock should be investigated. If the cause is deterioration or lack of spawning habitat, then rehabilitation of existing or creation of new spawning habitats should receive the highest management priority.
2. Lakes without spawning habitat should not be stocked, unless the objective of stocking is to provide a put-grow-take sport fishery.
3. Fry instead of fingerlings should be stocked in lakes where adequate quantities of suitable zooplankton are present at time of stocking. However, the number of fry used must be relatively large: a minimum rate of 200 fry·ha$^{-1}$ may be required. This means millions of fry may be needed for just one lake. Consequently, only a few lakes can be stocked each year, considering the number of fry that can be produced at the hatchery. Therefore, lakes for stocking should be carefully chosen on the basis of zooplankton food supply, forage fish abundance, spawning habitat and the status of native fish stocks.
4. To reduce costs, the more expensive fingerling

stocking should only be conducted in lakes where suitable zooplankton food source is scarce at time of stocking, but forage fish are abundant. A minimum stocking rate of 20 fingerlings·ha$^{-1}$ is recommended. The recommended minimum rates of stocking for fingerlings and fry are low, but are realistic in view of the numbers of fingerlings and fry that can be produced each year.

5. Stocking should be continued for a minimum of four years to provide enough year classes so that natural reproduction may restore a healthy self-sustaining stock.

6. The stocked walleye should be monitored and assessed for natural reproduction. Stocking should be discontinued if natural recruitment cannot be established. Creel surveys are needed to determine the contribution of stocked walleye to the sport fishery and to provide information for cost-benefit analyses.

**B. Lake specific**

**1. Greig Lake**

i. Construct artificial spawning reefs in the lake.

ii. Stock fingerlings at a rate of 60 fingerlings·ha$^{-1}$, or 97,200 fingerlings each year until natural recruitment is established.

2. **Turtle Lake**

   i. Construct artificial spawning reefs in the lake.

   ii. Stock fry at a rate of 200 fry·ha$^{-1}$ (approximately, 1,300,000 fry total), or 20 fingerlings·ha$^{-1}$ (128,000 fingerlings total) every other year until natural reproduction is capable of establishing a healthy self-sustaining stock.

   iii. Conduct a scale/otolith-pattern analysis to determine if discernible "checks" can be found to identify the origin of the walleye fingerlings (i.e., from rearing ponds, stocking or natural reproduction).

3. **Delaronde Lake**

   i. Rehabilitate spawning habitat in the tributary streams.

   ii. Stock 20 fingerling·ha$^{-1}$ (about 173,00 fingerlings total) every other year until natural reproduction is capable of establishing a healthy self-sustaining population.

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# 9. APPENDICES

**Appendix 1. Equations and an explanation of growth parameters of the three growth functions used in this study (Prager, et al. 1987; Moreau 1987).**

**1. von Bertalanffy Growth Function (VBGF)** - This widely used mathematical model in fishery science describes fish length as a function of age. Its equation is as follows:

$$L_{(t)} = L_{\infty} (1- \exp(-K(t-t_0)))$$

where $L_{(t)}$ is fish length and t refers to the age of the fish. The three parameters of the equation are: K, the VBGF growth constant; $L_{\infty}$, the asymptotic length - the mean length the fish would attain if they lived forever; and $t_0$, the hypothetical age at which the fish would have zero length if their growth conformed strictly to the VBGF - usually a small negative number.

The mean maximum length ($L_{max}$) of the fish can be approximated by:

$$L_{max} = 0.95 * L_{\infty},$$

and the time or age ($A_{0.95}$) it takes to attain the maximum size can be calculated by the equation:

$$A_{0.95} = (2.996/K) + t_0.$$

The above VBGF equation can also be used to describe growth in weight. In this case, $L_{(t)}$ and $L_{\infty}$ may be substituted with $W_{(t)}$ and $W_{\infty}$, respectively.

**2. Gompertz Growth Function** - This growth model has been used in fishery science in several forms to describe both growth in

length and in weight. A Gompertz curve is S-shaped having both a lower and a upper asymptote and an inflection point. The following equation is adapted:

$$W_{(t)} = W_0 * \exp\,(G(1-\exp(-gt)))$$

where $W_{(t)}$ is the weight, and t, the age of the fish. The three parameters are: $W_0$, a hypothetical weight when t=0; G, a growth parameter; and g, a second growth parameter. G*g is the size-specific instantaneous growth rate at t=0, and g is the instantaneous rate of decrease of this rate. The asymptotic size can be calculated as: $W_\infty = W_0 * \exp(G)$.

3. **Logistic Function** - This function is often used to describe population growth, but it can sometimes be used to fit growth in length or in weight. A logistic function is a sigmoid curve with an inflection point at Y=K/2. The following form is used:

$$Y_{(t)} = K \,/\, (1 + ((K-Y_0)/Y_0)\ (\exp(-rt)))$$

where $Y_{(t)}$ is the size of the fish at time t. The parameters are: $Y_0$, the fish size at t=0; r, the growth rate; and K, the asymptotic size.

Appendix 2. Details of net sets in Delaronde Lake in 1990.

**NS 1**: 274 m- standard gang gill net.
Location: northeast off Zigzag Island.
Water temperature: 22 C.
Date set: June 25, 1800 hr. Date lifted: June 26, 1300 hr.

| | Number of fish caught by mesh size and species | | | | | | |
|---|---|---|---|---|---|---|---|
| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
| depth(m) | 1.2 | 4.6 | 5.5 | 5.5 | 5.5 | 5.8 | 4.7 |
| walleye | 1 | 9 | 11 | 1 | 0 | 1 | 23 |
| n. pike | 4 | 28 | 19 | 0 | 0 | 0 | 51 |
| whitefish | 0 | 0 | 5 | 0 | 2 | 0 | 7 |
| w. sucker | 0 | 0 | 18 | 27 | 2 | 0 | 47 |
| cisco | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| y. perch | 6 | 0 | 0 | 0 | 0 | 0 | 6 |
| total | 11 | 37 | 53 | 28 | 4 | 1 | 134 |

**NS 2**: 274 m-long standard gang gill net.
Location: south of Hackett Creek inlet.
Water temperature: 20 C.
Date set: June 26, 1440 hr. Date lifted: June 27, 1010 hr.

| | Number of fish caught by mesh size and species | | | | | | |
|---|---|---|---|---|---|---|---|
| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
| depth(m) | 4.3 | 4 | 4.3 | 4 | 3.6 | 3 | 3.9 |
| walleye | 0 | 1 | 2 | 0 | 0 | 0 | 3 |
| n. pike | 5 | 10 | 29 | 2 | 0 | 0 | 46 |
| whitefish | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| w. sucker | 0 | 1 | 5 | 3 | 2 | 3 | 14 |
| cisco | 5 | 10 | 0 | 0 | 0 | 0 | 15 |
| y. perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| total | 10 | 22 | 36 | 6 | 3 | 3 | 80 |

Appendix 2 (continued). Details of net sets in Delaronde Lake in 1990.

**NS 3**: 274 m- standard gang gill net.
Location: southwest off Zigzag Island.
Water temperature: 20.9 C.
Date set: July 23. Date lifted: July 24.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 3.1 | 3.1 | 3.1 | 2.7 | 2.7 | 2.4 | 2.9 |
| walleye | 0 | 1 | 1 | 4 | 1 | 1 | 8 |
| n. pike | 5 | 6 | 8 | 1 | 0 | 0 | 20 |
| whitefish | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| w. sucker | 0 | 0 | 1 | 5 | 4 | 1 | 11 |
| cisco | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| y. perch | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| total | 8 | 7 | 10 | 11 | 5 | 2 | 43 |

**NS 4**: 274 m-long standard gang gill net.
Location: south of Hall Bay, west side of lake.
Water temperature: 20.9 C.
Date set: July 24. Date lifted: July 25.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 0.9 | 1.5 | 1.9 | 2.4 | 2.7 | 2.7 | 2.0 |
| walleye | 1 | 1 | 2 | 5 | 1 | 0 | 10 |
| n. pike | 2 | 8 | 45 | 4 | 0 | 0 | 59 |
| whitefish | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| w. sucker | 0 | 0 | 2 | 9 | 0 | 1 | 12 |
| cisco | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| y. perch | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| total | 6 | 9 | 49 | 18 | 1 | 1 | 84 |

Appendix 2 (continued). Details of net sets in Delaronde Lake in 1990.

**NS 5**: 274 m- standard gang gill net.
Location: small bay adjacent(west) to DPRR boat launch.
Water temperature: 21 C.
Date set: August 13, 1900 hr. Date lifted: August 14.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14.0 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 3.5 | 4.0 | 2.5 | 2.0 | 2.0 | 1.8 | 2.6 |
| walleye | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| n. pike | 7 | 14 | 20 | 2 | 1 | 0 | 44 |
| whitefish | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| w. sucker | 0 | 1 | 3 | 7 | 1 | 0 | 12 |
| cisco | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| y. perch | 5 | 1 | 0 | 0 | 0 | 0 | 6 |
| total | 12 | 16 | 24 | 9 | 3 | 0 | 64 |

**NS 6**: 274 m-long standard gang gill net.
Location: southeast off Zigzag Island in Zigzag Bay.
Water temperature: 21 C. Date set: August 14, 1235 hr.
Date lifted: August 15, 1130 hr.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14.0 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 4.0 | 3.5 | 2.0 | 1.5 | 1.0 | 1.8 | 2.3 |
| walleye | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| n. pike | 7 | 22 | 27 | 1 | 0 | 0 | 57 |
| whitefish | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| w. sucker | 0 | 0 | 1 | 23 | 7 | 1 | 32 |
| cisco | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| y. perch | 4 | 1 | 0 | 0 | 0 | 0 | 5 |
| total | 13 | 25 | 28 | 24 | 7 | 1 | 98 |

Appendix 2 (continued). Details of net sets in Delaronde Lake in 1990.

| | | | |
|---|---|---|---|
| **NS 20** | mesh: | 5.1 cm length: 20 m | |
| | location: | Zigzag Bay near Shore Pond | |
| | set: | June 25, 1990 at 1845 hr. | |
| | lifted: | June 26, 1990 at 1300 hr. | |
| | depth(m): | 1.2 - 1.8 | |
| | catch: | walleye | 2 |
| **NS 21** | mesh: | 5.1 cm length: 20 m | |
| | location: | entrance to Straight Bay | |
| | set: | July 23, 1990 | |
| | lifted: | July 24, 1990 | |
| | depth(m): | 1.8 - 2.1 | |
| | catch: | walleye | 1 |
| | | n. pike | 7 |
| | | w.sucker | 1 |
| **NS 22** | mesh: | 5.1 cm length: 20 m | |
| | location: | south end of island by Hall Bay | |
| | set: | July 24, 1990 | |
| | lifted: | July 25, 1990 | |
| | depth(m): | 1.8 - 2.1 | |
| | catch: | n. pike | 5 |
| **NS 23** | mesh: | 5.1 cm length: 20 m | |
| | location: | near Shore Pond in Zigzag Bay | |
| | set: | August 14, 1990 at 1235 hr. | |
| | lifted: | August 15, 1990 at 1100 hr. | |
| | depth(m): | 1 - 1.5 | |
| | catch: | n. pike | 9 |
| | | y. perch | 1 |

Appendix 3. Growth of stocked walleye in Greig Lake by year class.

| Year class | Date (m/d/y) | Grow days[1] | Age (yr) | FL_mm (mean) | FL_mm (SD)[2] | Wt-g (mean) | Wt-g (SD)[2] | Sample size |
|---|---|---|---|---|---|---|---|---|
| 89 | 08/01/89 | 0 | 0 | 82 | 9 | 6.0 | na[3] | 30 |
| 88 | 07/27/88 | 0 | 0 | 57 | 6 | 2.5 | na[3] | 48 |
| 88 | 10/14/88 | 79 | 0 | 128 | 5 | 20.9 | 2.3 | 13 |
| 88 | 08/04/89 | 373 | 1 | 174 | 7 | 53.3 | 4.7 | 3 |
| 87 | 07/14/87 | 0 | 0 | 48 | 2 | 1.1 | na[3] | 44 |
| 87 | 07/12/88 | 364 | 1 | 174 | 8 | 48.3 | 6.2 | 15 |
| 87 | 10/14/88 | 458 | 1 | 222 | 8 | 120.9 | 16.8 | 13 |
| 87 | 05/25/89 | 681 | 2 | 230 | 0 | 123.4 | 0.0 | 1 |
| 87 | 08/04/89 | 752 | 2 | 258 | 17 | 169.8 | 33.9 | 29 |
| 87 | 05/24/90 | 1045 | 3 | 288 | 21 | 268.2 | 70.3 | 5 |
| 85 | 07/23/85 | 0 | 0 | 56 | 3 | 1.8 | 0.3 | 40 |
| 85 | 07/12/88 | 1085 | 3 | 256 | 24 | 413.0 | 120.2 | 25 |
| 85 | 08/04/89 | 1473 | 4 | 428 | 20 | 887.5 | 124.1 | 16 |
| 84 | 07/18/84 | 0 | 0 | 56 | 5 | 1.8 | 0.4 | 38 |
| 84 | 07/12/88 | 1455 | 4 | 439 | 18 | 941.7 | 137.7 | 15 |
| 84 | 10/14/88 | 1549 | 4 | 450 | 15 | 1125.0 | 175.0 | 2 |
| 84 | 08/04/89 | 1843 | 5 | 509 | 10 | 1533.3 | 44.9 | 6 |
| 83 | 07/21/83 | 0 | 0 | 54 | 3 | 1.7 | 0.2 | 40 |
| 83 | 07/12/88 | 1818 | 5 | 531 | 20 | 1860.0 | 243.5 | 10 |

1. Number of days in lake after re-stocking;
2. SD=standard deviation;
3. na=not applicable: only one bulk weight of the whole sample was taken to determine the average individual weight.

Appendix 4. Details of net sets in Turtle Lake in 1990.

**NS 1:** 274 m-standard gang gill net.
Location: 1 km north of Indian Point. Water temperature:17 C.
Date set: June 11, 1530 hr. Date lifted: June 12, 0930 hr.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| walleye | 1 | 2 | 0 | 0 | 0 | 0 | 3 |
| n. pike | 3 | 4 | 4 | 1 | 0 | 0 | 12 |
| whitefish | 2 | 1 | 1 | 5 | 4 | 1 | 14 |
| w. sucker | 0 | 2 | 13 | 15 | 2 | 2 | 34 |
| cisco | 14 | 16 | 9 | 0 | 0 | 1 | 40 |
| y. perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| total | 20 | 25 | 27 | 21 | 6 | 4 | 103 |

**NS 2:** 274 m-standard gang gill net.
Location: 1 km south of Indian Point. Water temperature:
Date set: June 12, 1720 hr. Date lifted: June 14, 1630 hr.*

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| walleye | 0 | 2 | 0 | 0 | 0 | 1 | 3 |
| n. pike | 2 | 14 | 12 | 8 | 3 | 3 | 42 |
| whitefish | 0 | 0 | 0 | 4 | 5 | 2 | 11 |
| w. sucker | 0 | 1 | 5 | 35 | 18 | 5 | 64 |
| cisco | 4 | 113 | 114 | 0 | 4 | 3 | 238 |
| burbot | 0 | 0 | 1 | 2 | 0 | 0 | 3 |
| total | 6 | 130 | 132 | 49 | 30 | 14 | 361 |

*not lifted earlier due to extremely windy conditions. Two night catch is converted to one night catch by the formula: 2 night catch = 1.5 x 1 night catch (Kennedy, W.A. 1951. The relationship of fishing effort by gill nets to the interval between lifts. J. Fish. Res. Bd. Can. 8:264-274).

Appendix 4 (continued). Details of net sets in Turtle Lake i.. 1990.

**NS 3**: 274 m-standard gang gill net.
Location: off Kopp's Beach in south end of lake.
Water temperature: 19.1 C.
Date set: July 16. Date lifted: July 17.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 2.1 | | | | | 11 | 6.6 |
| walleye | 8 | 41 | 20 | 6 | 1 | 1 | 77 |
| n. pike | 0 | 5 | 17 | 9 | 2 | 0 | 33 |
| whitefish | 1 | 0 | 1 | 2 | 0 | 2 | 6 |
| w. sucker | 0 | 2 | 3 | 7 | 9 | 3 | 24 |
| cisco | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| y. perch | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| total | 11 | 48 | 41 | 24 | 12 | 4 | 142 |

**NS 4**: 274 m-standard gang gill net.
Location: off Kopp's Beach south of NS3. Water temperature:
Date set: July 17. Date lifted: July 18.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 0.9 | 1.5 | 1.8 | 2.4 | 2.7 | 2.7 | 2.0 |
| walleye | 9 | 26 | 20 | 12 | 0 | 0 | 67 |
| n. pike | 1 | 7 | 23 | 7 | 1 | 0 | 39 |
| whitefish | 1 | 0 | 0 | 1 | 2 | 1 | 5 |
| w. sucker | 0 | 4 | 7 | 7 | 4 | 0 | 22 |
| cisco | 1 | 1 | 1 | 0 | 0 | 0 | 3 |
| burbot | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| total | 12 | 38 | 51 | 27 | 7 | 2 | 137 |

Appendix 4 (continued). Details of net sets in Turtle Lake in 1990.

**NS 5**: 274 m-standard gang gill net.
Location: off northeast shore of Moonlight Bay.
Water temperature: 19.6 C.
Date set: July 30, 1300 hr. Date lifted: July 31, 0800 hr.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 1.5 | 2.4 | 3.0 | 3.4 | 4.6 | 5.2 | 3.4 |
| walleye | 1 | 0 | 1 | 2 | 0 | 0 | 4 |
| n. pike | 0 | 1 | 11 | 3 | 0 | 0 | 15 |
| whitefish | 1 | 0 | 1 | 2 | 1 | 2 | 7 |
| w. sucker | 0 | 0 | 18 | 9 | 4 | 0 | 31 |
| cisco | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| y. perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| total | 2 | 1 | 31 | 16 | 5 | 2 | 57 |

**NS 6**: 274 m-standard gang gill net.
Location: off south end of Byinatik Island.
Date set: July 31, 1230 hr. Date lifted: August 1, 0800 hr.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 5.8 | 5.1 | 5.2 | 4.6 | 3.4 | 2.7 | 4.5 |
| walleye | 2 | 4 | 1 | 0 | 0 | 0 | 7 |
| n. pike | 2 | 3 | 4 | 3 | 0 | 0 | 12 |
| whitefish | 1 | 0 | 0 | 1 | 2 | 1 | 5 |
| w. sucker | 0 | 5 | 9 | 10 | 17 | 14 | 55 |
| cisco | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| y. perch | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| total | 10 | 12 | 33 | 35 | 33 | 20 | 143 |

Appendix 4 (continued). Details of net sets in Turtle Lake in 1990.

**NS 91**: two partial standard gang nets, total length 120 m.
Location: north of Indian Point and NS1.
Water temperature: 17 C.
Date set: June 11, 1600 hr. Date lifted: June 12, 1130 hr.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| walleye | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| n. pike | 0 | 3 | 4 | 0 | 0 | 0 | 7 |
| whitefish | 1 | 0 | 0 | 1 | 0 | 2 | 4 |
| w. sucker | 0 | 1 | 4 | 12 | 9 | 1 | 27 |
| cisco | 5 | 4 | 5 | 1 | 0 | 0 | 15 |
| y. perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| total | 6 | 8 | 14 | 14 | 9 | 3 | 54 |

**NS 92**: two partial standard gang nets, total length 120 m.
Location: south of Indian point and NS1. Water temperature:
Date set: June 12, 1700 hr. Date lifted: June 14, 2100 hr*.

Number of fish caught by mesh size and species

| mesh (cm) | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 14 | total |
|---|---|---|---|---|---|---|---|
| depth(m) | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| walleye | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| n. pike | 1 | 5 | 8 | 4 | 1 | 0 | 19 |
| whitefish | 0 | 0 | 0 | 0 | 2 | 4 | 6 |
| w. sucker | 0 | 1 | 3 | 5 | 11 | 5 | 25 |
| cisco | 6 | 17 | 47 | 5 | 3 | 2 | 80 |
| burbot | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| total | 7 | 24 | 58 | 14 | 18 | 11 | 132 |

*see footnotes for NS 2.

Appendix 4 (continued). Details of net sets in Turtle Lake in 1990.

| | | | |
|---|---|---|---|
| **NS 93** | mesh: | 5.1 cm length: 20 m | |
| | location: | north of Kopp's Beach | |
| | set: | July 16, 1990 | |
| | lifted: | July 17, 1990 | |
| | depth(m): | 3 m | |
| | catch: | walleye | 1 |
| | | n. pike | 3 |
| | | whitefish | 1 |
| | | w.sucker | 1 |
| **NS 94** | mesh: | 5.1 cm length: 20 m | |
| | location: | north of Kopp's Beach | |
| | set: | July 17, 1990 | |
| | lifted: | July 18, 1990 | |
| | depth(m): | 1 - 1.5 m | |
| | catch: | walleye | 2 |
| | | n. pike | 5 |
| | | whitefish | 1 |
| **NS 95** | mesh: | 5.1 cm length: 20 m | |
| | location: | off northeast shore of Moonlight Bay | |
| | set: | July 30, 1990 at 1330 hr. | |
| | lifted: | July 31, 1990 | |
| | depth(m): | 2.7 m | |
| | catch: | n. pike | 2 |
| | | whitefish | 1 |
| **NS 96** | mesh: | 5.1 cm length: 20 m | |
| | location: | south of Eyinatik Island | |
| | set: | July 31, 1990 at 1230 hr | |
| | lifted: | August 1, 1990 at 0800 hr. | |
| | depth(m): | 1.8 m | |
| | catch: | walleye | 1 |
| | | n. pike | 2 |
| | | whitefish | 8 |